

TECHNICAL SPECIFICATION

FOR THE

FY '01 REPAIRS TO ELECTRICAL SYSTEMS EAST AND WEST AREAS, SCRAMJET POWER SUPPLY, WP#4

PART 1 SCOPE

1.1 SYSTEM DESCRIPTION

The NASA Langley Research Center's Arc-Heated Scramjet Test Facility, AHSTF, in building 1247B, is an electric arc-heated facility with air as the test gas. The test flow from the arc-heater and plenum chamber is expanded through a contoured nozzle into the test section. Downstream of the test section, the flow is diffused to subsonic velocity, cooled by an aftercooler, and exhausted into a vacuum sphere. AHSTF is used for tests of component integration models of airframe integrated scramjet engines at conditions experienced at flight Mach numbers of 4.7 to 8. Results are used to assess the performance of the scramjet, to optimize the design of the components, and to optimize fueling schemes. Examples of scramjet engines tested in this facility are the NASA 3-Strut, NASP SX-20, and the Hyper-X DFX engine.

The AHSTF has been in operation for scramjet testing since 1976. The two existing power supplies and associated equipment and controls are over 35 years old and require frequent maintenance. Much of the equipment is no longer manufactured and replacement parts are difficult to locate and expensive to replace. The existing power system does not allow real-time variation of arc power. During pre-operation procedures, operators set the power supply taps, which determine the power current/voltage curve. Duplicating test conditions usually require multiple attempts due to the age of the equipment.

This Specification establishes the performance requirements to provide the AHSTF with a new adjustable solid state Power Supply system. System features are specified to improve the monitoring, maintenance, production efficiency, and equipment life of the Power Supply.

1.2 WORK INCLUDED

The Contractor shall provide a completely Designed, Furnished, and Installed (DFI) Power Supply for the existing AHSTF. The Contractor shall perform the Power Supply system replacement as a "Turnkey" project, providing all materials, labor, and resources to engineer, design, procure, fabricate, inspect, test, deliver,

install, commission, and document the complete new Power Supply. The work shall include the following, but is not limited to:

- a. Project management including management plans, schedules, submittals, progress meetings, and progress reports.
- b. Engineering and design including studies, calculations, analyses, reviews, drawings, specifications, and test plans.
- c. Replace existing 6.6kV feeder breaker (3085), existing upstream air switch (3084), and existing interconnecting overhead bus duct with new components to connect with the new input isolation transformer.
- d. Direct current supply feeder cable and feeder bus modifications.
- e. New protective relaying system interfacing with the existing system distribution protection.
- f. New input isolation transformer including terminations, coils, tank core, conservator, cooling system, controls, equipment grounding, and factory and site tests.
- g. New harmonic filter network and power factor correction (if required) including capacitors, inductors, isolation switching devices, grounding switches, equipment grounding, and factory and site tests.
- h. Thyristor based, infinitely adjustable output, direct current Power Supply, including disconnecting means, grounding devices, cooling system, instrumentation, controls, equipment grounding, and factory and site tests.
- i. Trigger supply to initiate the plasma arc within the existing arc heater.
- j. Site construction including demolition of existing equipment, modifications to existing equipment, and installation of new Power Supply equipment and controls.
- k. Power Supply commissioning; including component and subsystem tests, integrated no load tests, arc-heater and controls operational tests, and load tests.

PART 2 APPLICABLE DOCUMENTS

2.1 STANDARDS

Work performed and materials furnished shall conform to the following standards to the extent specified herein. The publications shall be the most current issue as of the release date of this solicitation. Refer to Attachment A, Construction Specifications, for the mailing addresses of the standards organizations.

Equivalent international standards may be used in lieu of the standards specified only upon demonstration, by the Contractor, that the standards are equivalent.

American National Standards Institute (ANSI):

ANSI C2 National Electrical Safety Code

American Society of Mechanical Engineers (ASME):

ASME B31.3 Chemical Plant and Petroleum Refinery Piping

American Welding Society (AWS):

AWS D1.1 Structural Welding Code-Steel

AWS D1.3 Structural Welding Code-Sheet Steel

Federal Specifications (FS):

FS 595, #16473 Colors

International Electrical Committee (IEC):

IEC 146 General Requirements for Semiconductor Converters

Institute of Electrical and Electronics Engineers (IEEE):

IEEE 18 Standard for Shunt Power Capacitors

IEEE 295 Electronics Power Transformers

IEEE 428 Definitions and Requirements for Thyristor AC
Power Controllers

IEEE 519	Guide for Harmonic Control and Reactive Compensation of Static Power Converters
IEEE 1036	Guide for Application of Shunt Power Capacitors
IEEE C57.12.00	General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.13	IEEE Standard Requirements for Instrument Transformers
IEEE C57.16	Requirements, Terminology, and Test Code for Current Limiting Reactors
IEEE C57.21	Standard Requirements, Terminology, and Test Code for Shunt Reactors Over 500 KVA
IEEE C57.99	Guide for Loading Dry-Type and Oil Immersed Current Limiting Reactors
IEEE C62.1	Standard for Gapped Silicon-Carbide Surge Arrestors for AC Power Circuits
IEEE 63.12	Recommended Practice on Procedures for Control of System Electromagnetic Compatibility
IEEE Y32.2-75	Graphic Symbols for Electrical and Electronic Diagrams

National Electrical Manufacturers Association (NEMA):

NEMA IA 2	Programmable Controllers
NEMA CP-1	Shunt Capacitors
NEMA ICS 1	General Standards for Industrial Controls and Systems
NEMA SG 5	Power Switchgear Assemblies
NEMA ST 20	Dry Type Transformers for General Application
NEMA TR 1	Transformers, Regulators, and Reactors

National Fire Protection Association (NFPA):

NFPA 70	National Electric Code
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2.2

CONTRACT DRAWINGS

The following Contract Drawings apply to this work and are considered part of this Specification.

<u>DRAWING NUMBER</u>	<u>REV.</u>	<u>TITLE</u>
761538	B	Power Supply Site Plan and Drawing List
761539	C	Power One-Line Diagram, Existing
761540	B	Power One-Line Diagram, New
761541	B	Demolition Plan and Elevations, PS#1
761542	B	Demolition Plan, Rooms B-110 and B-111
761544	A	Demolition Views, PS#1
761545	A	Demolition Views, PS#1
761546	A	Demolition Views, Rooms B-110 and B-111
761554	B	New Power System Layout
761555	B	New Work Plan, Rooms B-110 and B-111
761556	A	Cooling Water Plan View
761557	A	Cooling Water Section Views

2.3 REFERENCE DRAWINGS

The following Reference Drawings contain information which may be useful in understanding the work of this Specification, and are for reference purposes only. The Reference Drawings are not part of this Specification.

<u>DRAWING NUMBER</u>	<u>REV</u>	<u>TITLE</u>
201452	F	Schematic-Part 2 Power Supply No.1 Breaker Control
201453	C	Schematic Power Supply No. 1 Auxiliary Devices
201454	N	Schematic PS#1 Annunciator Drops 1 - 6
201455	P	Schematic PS#1 Annunciator Drops 7 - 14
201456	T	Schematic PS#1 Annunciator Drops 15 - 26
201457	G	Schematic PS#1 Annunciator Drops 27 - 48
201458	C	Schematic Part1 PS#1 Motor Control Center
201459	B	Schematic Part 2 PS#1 Motor Control Center
201460	G	Schematic Part 3 PS#1 Motor Control Center
201461	C	Schematic Power Supply No.1 Load Tap Changer
201475	B	Wiring Power Supply No.1 Load Tap Changer Aux. Devices
201476	B	Wiring Power Supply No.1 Transformer TR1 Tap Changer Aux. Devices
201477	J	Wiring Power Supply No.1 Transformer TR2 Tap Changer Aux. Devices
651594	U	Wiring and Interconnection Control Panel No. 34
651595	F	Wiring and Interconnection Control Panel No. 33
651734	-	Arc Air Heater Power Supply Overall Oneline
651755	-	Arc Air Heater Power Supply No. 1 Oneline and Control Schemes

<u>DRAWING</u> <u>NUMBER</u>	<u>REV</u>	<u>TITLE</u>
651757	-	Silicon Rectifier Cubicle Wiring Diagram
651811	-	Scramjet Test Facility Interconnection Diagram
651812	-	Scramjet Test Facility Interconnection Diagram MCC Units 1-4
651813	-	Scramjet Test Facility Interconnection Diagram MCC
651814	-	Scramjet Test Facility Interconnection Diagram Resistors 1-8
651816	-	Scramjet Test Facility Interconnection Diagram Rectifiers 1-4
651823	G	Interconnection Box "Y" and Arc Heater Area
651837	1	Electric Arc Heater Foundation Mat Plan
651838	1	Electric Arc Heater Reinforcing Plan
659093	E	Kirk Key Interlock System
659094	D	Kirk Key Interlock System
659216	G	Interconnection Diagram Hydrogen and Air Control

PART 3 REQUIREMENTS

3.1 INTEGRATED SYSTEM REQUIREMENTS

3.1.1 SCOPE

The Contractor shall provide a complete replacement Power Supply for the AHSTF. This Power Supply shall achieve the design and performance requirements specified herein when the components are configured and operated as an integrated system.

3.1.2 PERFORMANCE

The new AHSTF Power Supply shall meet the following integrated system performance requirements.

3.1.2.1 Power Supply Configuration:

- a. The system topology shall be a phase-fired thyristor based, adjustable output, direct current Power Supply.
- b. Thyristors shall be connected in a minimum, twelve pulse, three phase, rectifier bridge configuration to provide power to the existing arc-heater.
- c. The Power Supply shall fit within the prescribe space of Building 1247B as indicated on the contract drawings, with sufficient clearance space for maintenance and code compliance.
- d. Power Supply components located outdoors shall operate in the environmental conditions local to the NASA Langley Research Center. Power Supply components located in Building 1247B shall operate in the local temperature and humidity conditions.
- e. The Power Supply shall be designed and configured to minimize the system complexity and maintenance.
- f. The Power Supply shall utilize cooling water from the existing building cooling water system to remove heat from the closed loop cooling circuit of the Power Supply.
- g. A new air switch and feeder breaker shall be provided for the new Power Supply.
- h. The downstream electrode of the existing arc heater shall be solidly grounded by the contractor.

3.1.2.2 Power Supply Electrical Characteristics:

- a. The Power Supply shall output infinitely variable power between 0 and 20 megawatts to the Arc-Heated Scramjet Test Facility based on Appendix A, Figure 1. The power supply output shall be configurable in two modes: Mode 1 is 3000 Amps at 6700 Volts. Mode 2 is 1500 Amps at 13,400 Volts.
- b. The duty cycle shall be two minutes on, every thirty minutes for an estimated 1,000 cycles per year.
- c. The Power Supply shall use a microprocessor controlled firing system, incorporating a programmable up and down power ramps with software programmable rate of rise and maximum amplitude limits.
- d. The Power Supply shall use a thyristor monitoring and fault annunciation system to determine the state of each thyristor during operation.
- e. The Power Supply output shall connect to the existing air switch as shown on the contract drawings. Interlock, mechanical Kirk™ locks, and permissives shall be provided, incorporated, and installed by the Contractor.
- f. The Power Supply filtering inductance shall be in compliance with the data shown in Appendix A, Figure 3.
- g. The Power Supply shall incorporate a trigger circuit to initiate the arc.
- h. The system efficiency from the point of common coupling, PCC, shall be of 98% or better at full load in either mode configuration.

3.1.2.3 Line Side Electrical Characteristics:

- a. The Point of Common Coupling (PCC) shall be defined as the connection point of the load side of the new 6.6 kV breaker 3085.
- b. The Power Supply shall perform within the input power harmonic restrictions as identified in IEEE 519.
- c. The line power factor shall not be less than 0.95 lagging and the supply voltage shall not rise above 7.5 kV due to leading power factor, for loads above 5 Megawatts, as measured at the Point of Common Coupling.

3.1.2.4 System Control:

- a. The Power Supply shall meet the operating envelope requirements defined in Appendix A, Figure 2.
- b. The steady state output current regulation shall be within $\pm 1\%$ of full load current for each configuration modes.
- c. The load current control loop shall have a minimum update rate of 500 Hertz.
- d. The Power Supply shall accept a serial and an analog current setpoint command from the existing facility control system.
- e. Discrete interface logic to the existing control system shall be optically isolated, high (24 VDC)= true, low (0 vdc)= false.
- f. Analog interface signals shall be optically or galvanically isolated, 0-10 VDC, 0 ± 10 VDC, or 4-20 mA, scaled to the corresponding engineering units. D/A converters shall be 12 bit or better resolution.
- h. Fiber optic links using fiber optic cable connections shall be monitored for cable and connector faults. Loss of optic communication shall be annunciated as an alarm condition.
- h. Hardwired circuits shall be fail-safe de-energized.
- i. Electrically Erasable Programmable Read Only Memory (EEPROM) circuits shall be used for Read Only Memory (ROM) applications within all processors.
- j. A serial communication link shall be provided from the converter controls to connect to the Government provided Allen Bradley Programmable Logic Controller control system.

3.1.2.5 System Reliability and Maintainability:

- a. The design life of the Power Supply shall be 35 years or more.
- b. The Mean Time Between Failures (MTBF) of the Power Supply shall be greater than or equal to 40,000 hours.
- c. The Power Supply Mean Time To Repair (MTTR) shall be less than or equal to 4 hours.

3.2 PROJECT MANAGEMENT

3.2.1 SCOPE

The Contractor shall provide the personnel and resources to manage all aspects of the project throughout the design, manufacture, installation, and commissioning of the new Power Supply system.

3.2.2 MANAGEMENT PLANS

3.2.2.1 Project Implementation Plan: The Contractor shall submit a Project Implementation Plan 30 calendar days after the Project Kickoff Meeting for approval by the Contracting Officer. The Project Implementation Plan shall describe the Contractor's approach to fulfilling the requirements of this contract, and shall include the following:

- a. A complete description of the project scope and content in sufficient detail to demonstrate a full understanding of the project requirements.
- b. The Contractor's plan for accomplishing the project elements and goals.
- c. A list of the Contractor's key personnel with resumes.
- d. Names and locations of design firms, with resumes of design personnel.
- e. A schedule of planned Design Reviews and Progress Meetings between the Government and the Contractor. Design Reviews and Progress Meetings shall be scheduled and administered in accordance with the requirements of this Specification.
- f. Names and locations of plants where the primary Power Supply components will be manufactured and tested.
- g. Names of subcontractors which the Contractor plans to use, and the Contractor's plan to manage the subcontractors.
- h. Construction management personnel and functions.

3.2.3 PERSONNEL

3.2.3.1 Key Personnel Technical Qualifications: The key personnel identified by the Contractor in the Project Implementation Plan shall have commensurate experience with the specific work elements required by this contract, and shall have the requisite education and training to perform the tasks by "best

practice" engineering using contemporary tools, methods, and technology.

3.2.3.2 Government Interface: The Contractor shall provide a single point of contact for communications and information to the Government. This Project Manager shall have thorough knowledge of the technical aspects of the project and be accessible (within 24 hours) to NASA Langley Research Center. This individual shall be available for communications during normal business hours from 9:00 AM to 3:00 PM Eastern Standard Time. The Government interface shall have authority within the Contractor's organization and with all subcontractors to direct changes, convey technical information, provide real time updates to the Contracting Officer, and shall be required to alert the Contractor and Government personnel of developments or changes that could impact the project schedule. The designated Government Interface cannot be changed during the contract period without the consent of the Government.

3.2.4 SCHEDULES

3.2.4.1 Critical Path Schedule: Within 30 calendar days after the Project Kickoff Meeting the Contractor shall submit a Critical Path Method (CPM) Schedule for approval by the Contracting Officer. The schedule shall be substantially similar to the proposal schedule. The schedule shall be in the form of a CPM procurement (supply) schedule and progress chart (resource loaded) drawn on a calendar days horizontal scale. The CPM Schedule shall be comprehensive of the entire project including design, manufacture, installation, and commissioning of the new Power Supply.

The schedule shall show the work broken down into a number of discrete tasks to be performed in specific areas. The duration of any discrete task shall not exceed four calendar weeks. For each task, the schedule shall show the earliest and latest start and finish times, indicate which tasks must start or be completed prior to the task in question, and define the float time, if any.

The schedule shall show which sequence of tasks represent the "critical path" for completion within the contract time. It shall also show the required order dates, fabrication times, and delivery dates for each major item of material or equipment. The CPM Schedule shall be coordinated with the Submittal Schedule to allow time for Government review of submittals, and Contractor resubmittal, if required.

Once the schedule is approved by the Contracting Officer, the Contractor shall baseline the initial schedule and shall not change or delete this baseline on all remaining schedule

submittals. This baseline shall be shown on each schedule submittal.

3.2.4.2 Monthly CPM Schedule Updates: The Contractor shall update the CPM Schedule on a monthly basis to reflect the progress of the project work elements and milestones. The Schedule Updates shall be submitted with the Contractor's monthly Progress Reports.

3.2.4.3 Supplementary Schedules: If, the Contracting Officer judges the Contractor to be behind the approved schedule, the Contractor shall submit a supplementary CPM Schedule, without additional cost to the Government, to demonstrate how the Contractor will regain the lost time and meet the original project schedule.

3.2.4.4 Construction Planning: The final completion date of this project and the duration of the AHSTF facility shutdown are critical. The Contractor shall time the construction work to coincide with the planned delivery of Power Supply components to minimize the AHSTF facility downtime. Site preparation may begin prior to delivery of Power Supply components. Site preparation may also begin prior to specified tunnel availability date.

The Contractor shall coordinate installation of the Power Supply components and sub-systems to expedite completion of the project and minimize AHSTF facility downtime. The Power Supply equipment which can be delivered and installed prior to AHSTF tunnel shutdown, and without interfering with AHSTF tunnel operations, may be worked at the Contractor's discretion as soon as site work approval, components, materials, and resources are available.

3.2.5 PROGRESS REPORTS AND PROGRESS MEETINGS

3.2.5.1 Progress Reports: The Contractor shall submit monthly Progress Reports throughout the duration of the project for Review by the Contracting Officer. The Progress Reports shall include the following:

- a. A narrative description of the project progress identifying areas of concern or potential problems.
- b. The monthly CPM Schedule Update.
- c. The monthly Submittal Schedule Update.
- d. Status reports of any equipment orders or subcontracts which could delay the overall schedule of the Power Supply manufacture, installation, or commissioning. These status reports shall include the following information.

1. Contract or purchase order number, date submitted to the supplier, date accepted by the supplier, the supplier's name, and the supplier's address.
2. Delivery date needed to meet contract schedule.
3. Original delivery date agreed to by the supplier and any subsequent changes in that date.
4. Reasons for changes in the original delivery date.
5. The effect which the latest promised delivery date will have on the contract schedule.
6. History of events by the Contractor to bring the promised delivery date in line with the requirements of the contract schedule, including negotiating overtime, expediting delivery costs, and efforts made to place the order or subcontract with other suppliers.
7. Name and title of the individual employed by the supplier who is cognizant of the order or subcontract status.
8. During manufacturing, the Contractor shall include digital pictures in a .JPG format to show progress of fabrication, manufacturing, and testing.

3.2.5.2 Scheduled Meetings: Progress Meetings between the Government and the Contractor shall be scheduled to discuss open issues, meet with subcontractors, and witness manufacturing or testing milestones. There shall be at least three Progress Meetings, scheduled throughout the manufacturing and factory testing phases of the project.

A Project Kickoff meeting shall be held at the beginning of the project immediately after contract award at a time mutually agreeable to the Contractor and the Government. This meeting shall be at NASA Langley Research Center. This meeting shall be used to discuss the complete project scope in detail, resolve logistic issues, gather site data, and plan upcoming site visits.

The Government may request additional meetings at any time, based on the review of the Contractor's technical or schedule performance. The Contractor shall support these meetings with the necessary personnel to resolve specific issues at no additional cost to the Government.

3.2.6 SUBMITTALS

3.2.6.1 Submittal Schedule: The Contractor shall submit a project Submittal Schedule within 30 calendar days after the Project Kickoff Meeting for Approval by the Contracting Officer. The Submittal Schedule shall list all submittals to be made throughout the duration of the contract. Submittals include design drawings, equipment specifications, test plans, test reports, engineering reports, and other documentation as required in this Specification and in Attachment A - Construction Specifications.

The Submittal Schedule shall indicate the status of all submittals, including submittal dates and submittal actions or dispositions.

3.2.6.2 Monthly Submittal Schedule Updates: The Contractor shall update the Submittal Schedule monthly to reflect the current status of submittals and submit the updated schedule with each monthly Progress Report.

3.2.6.3 Contractor Submittal Procedure: Submittals shall be prepared and submitted in accordance with the requirements of Attachment A - Construction Specifications, Section 01300, Submittals.

The submittal summary in Attachment A - Construction Specifications, Section 01330, Submittals, lists all submittals required by both the Technical Specification and Attachment A - Construction Specifications.

All submittals shall be in the English language.

3.3 ENGINEERING AND DESIGN

3.3.1 SCOPE

The Contractor shall provide all engineering and design personnel, equipment, and materials for the development of the new Power Supply system. This shall include system, subsystem, and component levels of effort. This shall also include demolition, installation, and integration activities to interface the new system hardware with the existing facility in a safe, efficient, and timely manner.

3.3.2 DESIGN CRITERIA AND METHODS

The following criterion identifies aspects of the design that the Contractor shall provide but is not necessarily all inclusive of details needed for a completely operational system.

3.3.2.1 System Configuration: The Contractor shall engineer and design a Power Supply system that meets all the requirements set forth in this Specification. The quantities of components are not fixed by this Specification in order to allow the Contractor and subcontractor(s) flexibility in meeting the technical requirements. The Contractor shall design the optimum configuration in consideration of performance, reliability, simplicity, initial cost, life cycle cost, harmonic content mitigation, efficiency, space constraints, demolition/installation requirements, tunnel downtime, maintainability, and implementation of the latest, proven state of the art technical designs and material developments.

3.3.2.2 Site Visits and Field Verification:

It is solely the Contractor's responsibility to gather and verify all existing system information required to design, manufacture, and install a Power Supply that correctly interfaces with all existing site conditions and operator controls. The Contractor shall notify the Contracting Officer 14 calendar days prior to visiting the site to allow for processing of site passes. In the case of foreign nationals, the Contractor shall notify the Contracting Officer 30 days prior visiting the site to allow for processing the site passes.

Existing facility documentation including drawings, design calculations, and any other relevant information will be provided to the Contractor upon request to assist in the design phase. These documents shall be for information purposes only, and the Contractor shall be responsible for field verification of all information critical to the design and installation of the new Power Supply system.

The Contractor shall field verify location of the water system connections, pump mounting, and source of the electrical power for the new water pump(s).

The Contractor shall field verify the location and connection to the new air switch and breaker, feeder bus duct, cables, breakers, relaying, and all other sub system components of the existing power source interface. The Contractor shall make recordings of the existing electrical voltage and current harmonic characteristics at the existing Point of Common Coupling, to establish a baseline of the existing levels of distortion prior to designing the Power Supply. If required to meet the IEEE 519 distortion limits and the power factor limitations, a harmonic filter shall be included. The Point of Common Coupling (PCC) shall be defined as the load connection point of the 6.6 kV breaker 3085.

The Contractor shall submit a copy of all data to the Government for review 10 days after field measurements are completed.

3.3.2.3 Manufactured Components and Materials: Components and materials provided under this contract shall be products of manufacturers regularly engaged in the manufacture of the specified products. Custom manufactured system components and prototypes will not be accepted. Where two or more units of the same equipment class or items are furnished, the equipment shall be from the same manufacturer and shall be exactly interchangeable. All materials and equipment shall be new and free from defects at the time of contract acceptance.

Manufactured items and materials to be incorporated into the work shall be handled, stored, applied, installed, serviced, and used in accordance with the manufacturer's instructions and recommendations.

3.3.2.4 Architectural Design: The design shall include provisions for satisfactory free space surrounding all mechanical and electrical equipment as appropriate to the overall system design and to meet applicable code requirements. Convenient access space and clearance for repair and maintenance shall be provided, including any permanent or removable platforms required to maintain equipment. Sufficient space for safe replacement of components shall be required.

Exterior of equipment and enclosures shall be uncluttered, with straight, plumb, and uniform arrangements. Any work to existing structures shall include all modifications to restore the building to original style, function, and structural integrity at no additional cost to the Government. The quantity of access/egress hardware, ductwork, vents, or equipment installed on the exterior of buildings, new or existing shall be minimized.

3.3.2.5 Electrical Design: The Contractor shall employ qualified, experienced electrical engineers familiar with medium voltage power distribution, solid state power conversion, filter networks, and digital control systems.

The Contractor's design shall include modification to the existing protective relaying system. New hardware shall be provided by the Contractor to meet the coordination requirements and to provide the proper protection of all new system components. This design shall include control, monitoring, protection, and time/current coordination with the existing power distribution system. Adjustable and nonadjustable protective devices shall be coordinated to operate on the minimum current that will permit distinguishing between fault and load current in a minimum of time. Time and current settings shall be selected for the adjustable devices that will operate in sequence with the nonadjustable devices to isolate a fault with a minimum of disturbance to the unfaulted portion of the system. The coordination shall start at the line side of the new air switch (3084) terminals and end at the arc-heater.

The Contractor's design shall include specific formal drawings that show equipment grounding details, conduit routing, equipment locations, interconnecting cabling, low voltage power distribution, control, and monitoring.

The Contractor's design shall include a method to easily isolate and ground the Power Supply and harmonic filters for maintenance and trouble shooting. These methods shall be mechanically interlocked to prevent energization of any equipment while the unit is grounded.

The Contractor's design shall include control system details with interface and interlock devices and logic. Local and non-supervised remote operation of the Power Supply shall be implemented in the design. Local operation shall be provided via a Contractor provided control panel at the Power Supply. Remote operation shall be implemented using the existing Government control system hardware and signals from the new Power Supply. Process and instrumentation design shall provide for correct operation of all utilities and the monitoring and recording of voltages, currents, pressures, flows, temperatures, and other system variables. The complete system shall incorporate, as a minimum, diagnostic and monitoring equipment, interposing relays, and signal conditioning to interface with the existing control system hardware.

The Contractor's electrical design shall identify on drawings all electrical interfaces between the new Power Supply and the existing AHSTF Heater sub-systems and components. The Contractor's design drawings shall indicate specific disconnection

points of existing electrical systems, and show how the new Power Supply electrical systems are integrated into the overall facility.

3.3.2.6 Mechanical Design: The Contractor shall employ qualified, experienced mechanical engineers familiar with power conversion equipment and supporting utility process systems.

The Contractor's design shall include detailed calculations for system component sizing and equipment selection. The design shall coordinate location and size of all new process lines and piping for the planned systems. The design data shall state heat loads, heat transfer, and all process design parameters. The design shall account for all existing piping and utilities and shall resolve any conflicts between existing and proposed new work. Design data shall be submitted to the Government for review. The Contractor shall prepare a Process and Instrumentation Drawing (P&ID) for the Power Supply cooling system showing all devices in the system in the proper and as-built locations in accordance with Instrument Society of America (ISA) P&ID documentation standards.

The Contractor's design shall identify the loads to be imposed on existing utilities by the new Power Supply, and proposed locations for utility connections.

The Contractor's mechanical installation drawings shall identify all mechanical and process interfaces between the new Power Supply and the existing AHSTF Arc Heater sub-systems and components. The Contractor's drawings shall indicate specific tie-in methods and locations to the existing mechanical and process systems; and show how the new Power Supply components are integrated into the overall facility.

See Appendix B for cooling water system data.

3.3.2.7 Kirk™ Locks: The Contractor shall design and provide a Kirk™ Lock system of safety-sequenced actions to protect personnel from the hazards of the new power supply. The Contractor shall be responsible for designing the interface to the existing Kirk™ Lock system and providing any design, components, and accessories required to integrate all new equipment into the existing Kirk™ Lock protection system.

3.3.2.8 Device List: The Contractor shall develop and maintain a complete project device list in Microsoft Excel™ for all components of the Power Supply system for the duration of the project. The device list shall contain, as a minimum, detailed information on each system valve, instrument, transducer, protective device, interlock device, all switches, and any other major components that significantly contribute to the operation of the system and requires calibration, maintenance, or repair. The

device list shall include a unique number, component definition, manufacturer, model number, part number, settings, outputs, alarm/trip values, calibration date, and drawing references in accordance with ISA recommendations.

3.3.3 ENGINEERING STUDIES AND CALCULATIONS

Engineering data required under this section shall include all calculations, computations, computer printouts, graphs, presentations, and details of design analysis. Analysis reports required under this section shall include all computer-aided design efforts for analysis of electrical, mechanical, and heat transfer parameters of the system. This shall be tabulated, organized, and bound in such a manner that all pertinent information such as transient conditions, maximum and minimum points, loads, limits, dimensional checks, references, and assumptions are easily and readily identified. The computed output shall be identified with headings to assist assimilation of data tables, and graphs. A summary of the problem statement and results of the computer analysis or simulations shall be provided in the report.

Any consulting engineering efforts employed by the Contractor that pertain directly or indirectly to the design and manufacture of this equipment resulting in any correspondence and information, reports, and data shall be submitted using the above format.

As a minimum, the following studies and calculations are required.

3.3.3.1 Short Circuit: The Contractor shall calculate three phase, line-to-line, and line-to-ground short circuit levels and X/R ratios at all major parts of the system from the PCC to the arc heater. Provide a single line diagram with bus and branch identification, as used in the study. Provide all calculation input data and assumptions. Perform a protective device evaluation study to confirm all equipment is applied within published ratings, in consideration of the worst-case short circuit fault current available. All calculations shall be verified using a documented, commercially available software program. The final short circuit study shall be submitted at the 90% Design Review.

3.3.3.2 Protective Device Coordination: The Contractor shall perform a protective device coordination study to select proper settings and device characteristics to provide optimum equipment protection, continuity of service, and complete selective coordination. Time/current curves shall be provided. These curves shall be plotted on a single piece of graph paper for those devices in series with each other using a common current scale, with current ratings at the lowest voltage level. Curves shall be plotted progressively as each circuit is studied, starting with

the device furthest from the source. Each curve on the graph shall include tolerance bands and shall show degree of coordination with each successive device. Furnish standard time/current curves for each protective device provided. Assume worst case short circuit fault current available for coordination margin determinations. Furnish breaker and relay settings in a tabulated format. Include power supply control trip characteristics on time/current curves. Where harmonic content might affect relay operation if standard practices are employed, make specific provisions in the design and selection of components to assure proper equipment protection and selective coordination. The Contractor shall check existing relaying to assure harmonic distortion is not an error-introducing factor to the existing system components. If so, the Contractor shall replace with non-harmonic sensitive components or redesign such that harmonic sensitivity is not error introducing. The Contractor shall document any deviations from standard practices based on harmonic content impact. The final coordination study shall be submitted at the 90% Design Review.

3.3.3.3 Harmonic Analysis and Filter Design: The Contractor shall perform a harmonic analysis on the power system to determine harmonics introduced by the Power Supply at all loads up to the 25th harmonic, and design a filter that complies with IEEE 519 and the existing network impedance. The Contractor shall perform a simulation to verify that filter network characteristics meet design requirements over the system operating range. The final harmonic analysis report shall be submitted at the 90% Design Review.

3.3.3.4 Efficiency Calculations, Load Calculations and Voltage Regulation Analysis: The Contractor shall provide load calculations to determine the size of system components, cabling, interconnections, and source requirements. The Contractor shall provide voltage regulation profiles for equipment buses over the extremes of Power Supply and load configurations.

The efficiency calculations shall be validated using industry-recognized methods. The results shall be tabulated and included as a section of the load calculations. The final calculations and analysis report shall be submitted at the 90% Design Review.

3.3.3.5 Insulation Coordination: The Contractor shall determine and document the Basic Insulation Level (BIL), and Basic Switching Level (BSL) ratings, as well as surge protection equipment requirements for 'best practice' system design. The component insulation ratings shall be coordinated with the system design requirements. The final insulation coordination study shall be submitted at the 90% Design Review.

3.3.3.6 Subsystem and System Reliability Analysis: The Contractor shall provide a tabulated and graphical analysis of the

reliability factors of the Power Supply. This shall be based on data compiled from in situ components and subsystem configurations previously installed by the Contractor, related to the specific hardware arrangement for this Power Supply. This report shall list data base systems, and the length of time in service. The analysis shall determine and list the most probable failure modes, value of the supplied redundant configuration, and justify the final system design by conclusive evidence of optimized availability. The final reliability analysis report shall be submitted at the 90% Design Review.

3.3.3.7 Predictive Maintenance Plan: The Contractor shall provide a plan for the predictive maintenance of the Power Supply system. This plan shall cover all provided equipment, and be based on Reliability Centered Maintenance techniques. The final Predictive Maintenance Plan shall be submitted at the 90% Design Review.

3.3.4 DESIGN REVIEWS

3.3.4.1 General: Three Design Reviews shall be scheduled throughout the design phase of the project. For each review, the Contractor shall submit the meeting agenda and technical materials to be reviewed by the Government 14 calendar days prior to the meeting. The Contractor shall be flexible in modifying the design based upon the Government's review comments, and some design iterations are to be expected. The Contractor is not required to stop design work in order to complete the design reviews.

3.3.4.2 15 Percent Design Review: The Contractor shall conduct a 15 Percent Design Review no later than 45 calendar days after the Project Kickoff Meeting. The 15 Percent Design Review shall be a formal presentation by the Contractor, and shall be held at the Contractor's facilities. Between two and five Government representatives will attend the review. The Contractor shall include the following information in the 15 Percent Design Review.

- a. Engineering basis for design.
- b. Major equipment list and specifications.
- c. Results to date of engineering studies.
- d. List of drawings.
- e. Identification of long lead time items.
- f. Compliance with applicable codes.
- g. Electrical one-line diagram(s).
- h. Electrical load calculations.

- i. Sequence controller configuration defining racks, processors, gate firing control, type and quantity of type of I/O.
- j. Analog signals for data system recording.
- k. Control system block diagrams.
- l. Power Supply electrical, mechanical, structural, and utility details.
- m. Utility Process and Instrumentation drawings.
- n. Piping routing layouts.
- o. Equipment dimensions and layout drawings.
- p. Preliminary copies of all required studies and reports.

3.3.4.3 Interim Review: The Government will hold an informal, interim review of the Contractor's design documentation when the design is approximately 50 percent complete. The review will be held at the NASA Langley Research Center no later than 120 calendar days after the Project Kickoff Meeting. The Contractor is not required to attend the review, however, the Contractor shall submit a complete set of all design documentation to be used as the review material no later than 10 days prior to the stated review date. The design material shall include refinement and progress of the 15 Percent Design Review information, plus the following additional information.

- a. Description of system operation and sequence of operation.
- b. Details and data for electrical one-line diagram.
- c. Electrical schematics.
- d. Control loop diagrams.
- e. Sequencer programming documentation.
- f. Facility wiring interface details.
- g. Control panel details.
- h. Service and equipment grounding details.
- i. Facility Kirk™ Lock interface.
- j. Mechanical plans and sections.

- k. Mechanical equipment and details.
- l. Demolition details and schedule.
- m. Installation details and schedule.
- n. Factory tests details and schedule.
- o. Power Supply power bridge design details.
- p. Cooling system interface design, including P&ID.

3.3.4.4 90 Percent Design Review: The Contractor shall conduct a 90 Percent Design Review at the Contractor's facility no later than 180 calendar days after the Project Kickoff Meeting. The 90 Percent Design Review shall be a formal presentation by the Contractor and shall include updates to all of the items listed in section 3.3.4.3, submittal of 90% complete drawings, equipment specifications, all design and construction details, programming documentation, and updates to any previously submitted information. The review shall be scheduled for two consecutive days to cover all aspects of the project design, manufacturing, installation and to discuss and resolve all issues arising out of the main design review presentation.

3.3.5 Power Supply Documentation

3.3.5.1 Scope: In addition to documentation required in other sections of this Specification, the Contractor shall submit all Power Supply documentation required to describe the Power Supply design, programming, manufacture, installation, commissioning, operation, and maintenance. Unless otherwise specified, all documentation, including drawings, manuals, catalog cuts, and all Contractor submittals, shall be in the English language.

All drawings, calculations, and analyses shall be prepared under the supervision of experienced, degreed engineers with direct experience related to the specific requirements of this contract. All documentation shall be checked and approved by the appropriate engineering supervision prior to submittal to the Government. Documentation shall utilize conventional symbols as recognized in the applicable standards as referenced in Section 2.0.

The Contractor shall submit Power Supply documentation for review by the Contracting Officer in accordance with Section 3.2.6 of this Specification. All submittal documentation shall become the property of the Government.

Final drawing submittals shall include a software copy of all CAD drawings. Final submittals of all text documents shall be in Microsoft Word format with charts and graphs in Microsoft Excel

format. Any exceptions shall be brought to the attention of the Contracting Officer and approved prior to submission.

3.3.5.2 Drawings: The Power Supply drawings shall include, as a minimum, layout drawings, component drawings, demolition drawings, installation drawings, interconnection drawings, schematic drawings, and point-to-point wiring drawings for the major systems, subsystems, and components of the new power supply. This shall include, but not be limited to, the following drawing details:

a. Input/Isolation Transformer(s):

1. Assembly and layout with physical data.
2. Cooling system components and controls.
3. Lifting, rigging, and structural supports.
4. Connection terminations and bushings.
5. Radiator size, weight, and connection details.
6. High and low voltage connection diagrams and bushing arrangements.
7. Control wiring diagrams.
8. Structural steel work for primary connection to existing circuit breaker.
9. New cable and bus work installation details.
10. Civil work for installation and mounting of transformer(s).

b. Filter Network:

1. Filter equipment layout plans and sections.
2. Filter network arrangement.
3. Equipment foundations and structural steel work.
4. Connection diagrams.
5. Schematics and control components wiring diagrams.

c. Power Supply:

1. Assembly and layout with parts lists.
2. Thyristor stack assembly details.
3. Firing circuit assembly.
4. Snubber circuit assembly.
5. Control and monitoring systems assembly, schematics, and wiring diagrams.
6. Interface diagrams to the existing facility control system showing serial and hardwired connection points, signal definitions, and wiring.
7. Power conversion schematics and wiring diagrams.
8. Cooling system process schematics, interlocks, and wiring diagrams.
9. Power terminations and connection details.
10. Enclosure assembly and physical data.
11. Location and layout including anchor bolt locations.

12. Electrical interface from switchgear and input isolation transformer(s) controls.
13. Cable installation from Power Supply to existing air switch.
14. Cooling water system modifications and P&ID.
15. Serial interface details.
16. Analog signal loops, shielding, scaling, and engineering units.

d. Site Construction:

1. Overall demolition layout drawings identifying the existing components to be demolished, salvaged, or relocated.
2. Rigging and cribbing drawings showing lifting and transporting arrangements for the major Power Supply components.
3. Demolition drawings of existing cables.
4. Building modifications drawings.
5. Installation drawings.
6. Ground grid connections for new equipment.
7. New concrete foundations.
8. Structural steel erection drawings.
9. Interface with existing foundations.
10. Interface with existing cable trays and racks.

The Contractor's drawings shall use identical backgrounds wherever possible. Final submittal drawing size shall be D size (22 X 34 inches). All drawings developed for this project shall be compatible with AutoCad Version 14 or later. A NASA Langley Research Center border and content entity data file will be supplied to the Contractor at contract award for uniformity with existing NASA Langley Research Center facility drawings. All drawings shall be properly created scaled, and field verified for accuracy. A list of drawing numbers will be provided to the Contractor.

Drawings shall be developed and presented in a professional manner by designers familiar with proper representation of the disciplines depicted on the drawings. Sketches, hand drawings, vague drawings, and lack of detail will not be acceptable. All drawings shall be submitted for review by the Government and the Contractor shall revise, modify, redraw, or provide additional drawings or details as required by the Government's review.

Drawings shall be prepared to facilitate the review of all disciplines and to ensure that the Power Supply equipment fits into the real estate limitations applicable to each work area. The floor plans and building sections represent critical limitations. Major equipment shall be accurately drawn to scale such that all design disciplines can identify space allocations

and restrictions. The design shall allow for service, removal, code compliances, and shall not cause interference with any existing equipment.

3.3.5.3 Engineering Data: The Contractor shall submit Engineering Data, for review by the Contracting Officer, as part of the project final documentation. The Engineering Data shall include, but not be limited to the following details.

- a. Analyses, calculations, reports, and other documentation as required in other sections of this Specification.
- b. Power Supply performance data including efficiency, circuit parameters, and losses.
- c. Interlock sequences and definitions.

3.3.5.4 Certified Inspection Reports: The Contractor shall submit Certified Inspection Reports, for review by the Contracting Officer, for all equipment and material inspections performed throughout the manufacturing and installation phases of the project. Inspection Reports shall be submitted within 21 calendar days after completion of the inspection.

3.3.5.5 Test Procedures: The Contractor shall submit, for review by the Contracting Officer, all test procedures and plans for the factory and site testing of major Power Supply sub-systems, equipment, components, or materials. Test procedures shall be submitted 10 calendar days prior to the start of testing.

3.3.5.6 Certified Test Reports: The Contractor shall submit Certified Test Reports, for review by the Contracting Officer, for all tests of major Power Supply sub-systems, equipment, components, and materials. Test Reports for factory tests, on site sub-system tests, and commissioning tests shall be included. Test Reports shall be submitted within 21 calendar days after completion of the test.

3.3.5.7 Operation Manuals: As part of the project final documentation, the Contractor shall submit Operating Manuals for review by the Contracting Officer. Operating Manuals shall include, as a minimum, the following details.

- a. Start-up procedures including the detailed steps required to configure the system for operation and calibration of system instrumentation.
- b. Operating and control sequences of the overall Power Supply and the Power Supply sub-systems.
- c. Operating check lists describing the Power Supply parameters which require monitoring during operation, the safe

operating limits of these parameters, and the required operator actions when safe limits are exceeded.

- d. Procedures for shutdown and grounding of the Power Supply.

3.3.5.8 Maintenance Manuals: As part of the project final documentation, the Contractor shall submit Maintenance Manuals for review by the Contracting Officer. Maintenance Manuals shall include, as a minimum, the following details.

- a. Step-by-step procedures for dismantling and reassembling the Power Supply equipment, including recommended handling techniques.
- b. Procedures for replacing process system parts, such as pumps, filters, bearings, packings, and seals.
- c. Information regarding clearances and tolerances.
- d. A listing and description of periodic maintenance and inspection requirements for the Power Supply equipment.
- e. Bolt torques of critical Power Supply fasteners.
- f. Calibration settings, tolerances, and intervals of calibration for Power Supply instrumentation.
- g. A trouble-shooting guide to aid in diagnostics of Power Supply faults and trips.

3.3.5.9 Spare Parts Lists: The Contractor shall maintain an internal distribution network that provides sufficient replacement parts to be available for the design life of the Power Supply. As part of the project final documentation, the Contractor shall submit a Spare Parts List for all equipment included with the complete Power Supply. The Spare Parts List shall include vendor names, catalog numbers, parts cost, and delivery lead times for parts which aren't normally stocked.

3.3.5.10 Vendor Catalog Data: As part of the project final documentation, the Contractor shall submit, for review by the Contracting Officer, product literature, catalog cuts, and specifications of major purchased components of the Power Supply.

3.3.5.11 Certificates of Compliance: The Contractor shall submit Certificates of Compliance, for review by the Contracting Officer, which demonstrate that the Contractor, subcontractors, and vendors provided equipment and materials which complied with the applicable standards, codes, and specifications.

3.3.5.12 As-Built Drawings: The Contractor shall keep a set of drawings, marked "AS-BUILT", to record actual or as-built

information. This drawing set shall include all contract, reference, shop, and field drawings; and be kept exclusively for this purpose only.

The Contractor shall update all entries on this set of documents concurrently with the changes being made. All as-built changes shall be shown where there are any deviations from the original drawings, including change orders, modifications, clarifications, and field instructions and/or verifications.

The Contractor shall keep all as-built documents current, making them available for inspection at any time by the Contracting Officer. The Contracting Officer will review the progress of the as-built documents on a monthly basis.

At the completion of the Power Supply commissioning, all drawing files shall be revised to incorporate the as-built or actual conditions. This set of documents shall include a revision that states 'As-Built Condition' on each sheet or page, dated, signed by the Contractor, and delivered to the Contracting Officer prior to final acceptance of the contract. In addition, each final drawing hard copy and file shall be modified to include information regarding the Government's classification of LaRC's Configuration Control Management system. This classification data will be supplied by the Government to the Contractor 30 days after all final drawings have been submitted to the Government for review.

3.3.5.13 Software Documentation: All programming and configuration software and information for the Power Supply shall be provided and be fully documented. This documentation shall include logic printout, I/O cross reference, label printouts, rack addressing, system architecture, and diagrams for high speed or serial communications, including remote/local networks.

Software for the Power Supply controller shall be provided on storage media that can be remotely stored and used to restore machine software with all operating parameters and soft limits to return the system to normal operating conditions via the supplied programming terminal. Software code and instructions shall be provided to the extent to allow the Government to adjust soft limits in the future. Listings shall be provided to document and troubleshoot the power supply controller.

3.4 INPUT ISOLATION TRANSFORMER

3.4.1 SCOPE

The Contractor shall design, manufacture, furnish, and install an Input/Isolation Transformer to provide the proper voltage and power to the Power Supply.

3.4.2 PERFORMANCE REQUIREMENTS

The Input/Isolation Transformer shall meet or exceed the performance requirements described in this section.

3.4.2.1 Transformer Voltages: The transformer shall be designed for connecting to the existing 6.6 kV power distribution grid at NASA Langley Research Center. The output voltage shall be determined by the Contractor and shall be matched to the requirements of the Harmonic Filter and DC Power Supply.

3.4.2.2 Transformer Power Rating: The transformer shall have sufficient rating to meet all requirements of this Specification and IEEE C57.12.00. The transformer rating shall be intermittent and shall be based on temperature rise. Temperature limits shall not be exceeded when the transformer is delivering the rated output at rated secondary voltage in accordance with IEEE C57.12.00, including harmonic content.

3.4.2.3 Transformer Phasing: All equipment, including auxiliary equipment shall have voltage applied with positive (A-B-C) phase sequence.

3.4.2.4 Impedance: The transformer impedance shall be selected by the Contractor to match the Power Supply system requirements and provide a maximum short circuit current at the transformer secondary less than the rated short circuit current of the Power Supply. In addition, the transformer shall withstand the mechanical and thermal stresses produced by external short circuits.

3.4.2.5 Reliability: The Input/Isolation Transformer shall provide commercial quality reliability with a design life of 35 years.

The transformer shall be designed to operate without damage or reduction in design life while subjected to the harmonic amplitudes and frequencies generated by the Power Supply under all load conditions.

3.4.2.6 Maintainability: Routine maintenance of the transformer shall not exceed eight hours per year, by design. Self-diagnosis and interlock alarms shall be designed into the transformer controls to monitor and indicate malfunctions. Components that may require replacement, calibration, or maintenance shall be easily accessible through doors, manholes, or removable panels. Mounting methods and fasteners shall provide for rapid and unobstructed removal and replacement of devices.

The Contractor shall provide a recommended spare parts list with costs, in order to minimize the mean-time-to-repair (MTTR). This

shall be broken into two categories: 1) Parts required to keep MTTR below 24 hours; and 2) Parts required to keep MTTR below 10 calendar days.

3.4.2.7 Sound Levels: The transformer sound level in decibels shall not exceed the values determined by IEEE C57.12.90.

3.4.2.8 Safety: The transformer shall be designed and constructed to meet all safety requirements of NEMA TR1 and NFPA 70. All equipment, within eight feet of the ground, shall be in grounded metal enclosures, with no exposed live parts. Maintenance access ports shall be equipped with provisions for padlocking. Interlocking switches shall be employed where needed to protect maintenance personnel.

3.4.3 HARDWARE REQUIREMENTS

The input isolation transformer shall meet or exceed the hardware requirements described in this section.

3.4.3.1 Input Isolation Transformer Design and Construction:

The Contractor shall provide a new input isolation transformer to match the existing supply to the input voltage, impedance, phase, and isolation requirements of the new Power Supply system. The input isolation transformer shall be a rectifier type designed, constructed, and factory tested in accordance with IEEE C57.12.00, and C57.12.1 for Class I power transformers, and IEEE C57.18.10 for semiconductor power rectifier transformers. The transformer shall be oil filled and OA or OA/FA cooled. The basic design and construction of the transformer shall also include the following:

- a. Current carrying components shall be copper (i.e. windings, bus, bushings, and connecting hardware).
- b. Primary winding Basic-Impulse Insulation Level (BIL) shall be 95 kV.
- c. The transformer shall be electrostatically shielded.
- d. Current carrying joints and splices shall be welded, brazed, or made by compression fittings; soldered connections shall not be used.
- e. All leads not directly brought to bushing terminals or tap changers shall be brought to terminal boards constructed over insulation materials rigidly supported inside the case.

3.4.3.2 Coils: High and low voltage coil sections shall consist of insulated copper conductors assembled around the core. Coil sections shall be concentric or rectangular to counteract forces incurred under short circuit conditions and shall be provided with

oil ducts to dissipate the heat generated in the windings. Coil sections shall be electrically connected together, and to the respective terminal bushings of the transformer.

3.4.3.3 Tank: Walls, bottom, and cover of the transformer tank shall be fabricated from hot-rolled steel plate. The configuration shall be designed to best take advantage of the allotted space.

The transformer tank shall be welded construction with an enclosed rectangular base using I-beam construction. It shall be designed for rolling in the direction of the centerline of the bushing segments.

The tank shall be provided with two ground pads, located on opposite sides of the tank, and two bolt clamp type terminal connectors suitable for 4/0 AWG copper cable.

Sealed tank construction with a welded main cover shall be provided. The tank shall have a manhole in the cover. Circular manholes shall be greater than 15 inches in diameter. Rectangular or oval manholes shall be greater than 10 by 16 inches. All openings, which may be used during the normal course of operation, shall be designed to remain oil tight after re-assembly.

The transformer base shall be designed to provide natural draft ventilation under the transformer tank when the transformer is placed on a flat concrete foundation. The bottom of the transformer tank shall be undercoated with a heavy rubberized, asbestos-free, protective sealant a minimum of 1/32 inches thick.

The transformer shall be provided with an oil preservation system. The Contractor may chose an automatic gas control system or a conservator type system. Requirements for each type of system are provided below.

The automatic gas control system shall consist of a NEMA 3R enclosure with one nitrogen gas cylinder, regulator(s), relief valve, alarm and trip pressure switches, supply and isolation valves, and all accessories. A magnetic oil level gauge and rate of rise pressure switch with calibrated alarm and trip contacts shall be included.

The conservator type system shall consist of an adequately sized oil conservator tank, constructed of mild steel, mounted on top of the transformer at a height sufficient to maintain the design pressure head on the transformer tank and its components. An oil resistant, nylon reinforced bladder shall keep the oil from direct contact with the atmosphere. The conservator shall be vented through a silica-gel breather such that the air side of the bladder is kept moisture free. The breather shall have a visual indicator to show the relative moisture contained in the silica

gel. The conservator tank shall be equipped with fill, drain, and sample valves. A Buchholtz relay shall be included and calibrated to signal an internal fault and activate the alarm contacts on low insulating fluid. A slow gas build up shall also activate the alarm contact. The relay shall instantaneously activate the trip contact when subjected to a high level fault which causes a high gas flow. The device shall allow for sampling of the suspect gas for further analysis.

The transformer tank shall be designed to withstand an internal pressure of 10 psig and an internal vacuum of 10 microns.

The tank shall include the following accessories.

- a. A globe type combination drain and lower filter valve (2 inch NPT) with sampling device. The drain valve and the oil sampling valve (3/8 inch NPT) shall be located to allow draining and/or sampling from the bottom surface of the tank.
- b. A dial type winding temperature indicator with sequential relay contacts.
- c. A dial type oil thermometer with sequential relay contacts and a 4-20 mA output for a remote readout device.
- d. A pressure-vacuum gauge with alarm contacts.
- e. A pressure-vacuum bleeder valve
- f. A globe type upper filter valve (1 inch NPT)
- g. A cover-mounted, automatic resealing and resetting, mechanical relief device with discharge pointing downward. The relief device shall incorporate electrical contacts and mechanical indication of operation.

Dial or needle type gauges and valves associated with like processes shall be grouped together on the low voltage side of the transformer for easy accessibility and maintenance. All gauges over 96 inches from ground level shall have their faces tilted down at an angle of 30 degrees from vertical. Wells for thermometer sensors and liquid level gauge floats shall be outside the main tank.

3.4.3.4 Core: The core shall be built up with laminated, non-aging, high-permeability, grain-oriented, cold-rolled, silicon sheet steel. Laminations shall be coated with an insulating film or finish to minimize eddy current losses. Sheet steel shall conform to ASTM 345.

The core(s) shall be grounded to the tanks through a detachable connector and ground lead.

3.4.3.5 Bushings: Primary and secondary windings of the transformer shall be terminated in cover mounted, copper constructed bushings. The insulation class of the bushings shall be the same as the insulation class of the windings to which they are connected. The neutral secondary bushing shall be located on the transformer cover. The dimensions of transformer bushings shall be in accordance with IEEE 21. Bushings shall be provided with liquid level indication and provisions for power factor testing.

3.4.3.6 Current Transformers: Current transformers on primary and secondary bushings, not including current transformers for winding temperature indication, shall be as follows:

- a. Two, multi-ratio current transformers sized appropriately by the Contractor with accuracy of Class 400 minimum shall be installed on each primary line bushing.
- b. Two, multi-ratio current transformers sized appropriately by the Contractor with accuracy of Class 400 minimum shall be installed on each secondary line bushing.

3.4.3.7 Oil: The transformer shall be provided with Type II mineral insulating oil conforming to ASTM D3487, Table 1, with inhibitor. Dielectric strength of transformer oils, when shipped shall be not less than 28 kV when measured in accordance with ASTM D117

Askarel and insulation liquids containing polychlorinated biphenyls (PCB) shall not be used.

The Contractor shall fill the transformer with oil at the site using as high a vacuum as possible in accordance with IEEE C57.12.00.

3.4.3.8 Surge Arrestors: One station valve type surge arrestor shall be connected to each primary bushing of the transformer. The design, fabrication, testing, and performance of arrestors shall comply with IEEE C62.1, NEMA LA 1, IEEE C57.12.00 and as specified herein.

The voltage rating of arrestors shall be selected to meet the maximum line to line voltage of the system. The system neutral, whether grounded, ungrounded, or resistor grounded for all possible conditions of operation, shall be considered when selecting arrestors.

Nonferrous hardware shall be used with wet-process, high strength porcelain housings to provide completely sealed assemblies.

Arrestors shall be the single phase, single pole, self supporting type, designed for pedestal, platform, or bracket mounting.

Mounting hardware shall be supplied with each arrestor. Arrestors shall be installed and connected as part of the transformer auxiliary apparatus. Arrestors shall be directly grounded to the ground pads located on either side of the tank.

3.4.3.9 Tap Changer: The transformer shall be equipped with a primary, manual, no-load tap changer. The primary winding shall be designed and equipped with four 2.5 percent full capacity taps, two above and two below the nominal voltage of 6,600 Volts, brought out to an externally operated manual tap changer. The tap changer handle shall be capable of being padlocked in each tap position and shall only be operable when the transformer is de-energized.

3.4.3.10 Differential Relay Protection: A differential current relay shall be provided to detect a percentage current differential across the transformer. The relay shall consist of a percentage differential unit with harmonic restraint, indicating contact switch, and instantaneous trip. Relays shall be designed for operation on a 125 VDC control circuit.

The case shall be semi-flush mounted to the hinged instrument panel of a local relay panel or the transformer control panel.

3.4.3.11 Lock-out Relay Device: A lock-out relay shall be provided and shall be a hand-reset, high speed type for use with the differential relays, transformer level, and temperature devices to protect the transformer. The relay shall be configured to trip the transformer primary circuit if any of the transformer protection devices are activated.

The relay shall be furnished with at least ten (10) electrically separate form C contacts, and two (2) normally closed contacts pre-wired for opening the operating coil.

The relay shall be designed to operate on a 125 VDC control circuit. Relay contacts shall be rated for 10 ampere continuous duty at 125 VDC /120 VAC, and 50 ampere for 1 minute duty. Relay trip time shall be less than 15 milliseconds.

3.4.3.12 Cooling: The transformer shall be designed for continuous self-cooled or fan-cooled operation (OA or OA/FA). The average winding temperature rise over ambient as measured by resistance shall not exceed 65 degrees C for continuous operation, with 40 degrees C ambient.

The cooling equipment shall include a thermally operated control device, manually operated bypass switch, motor driven fans, electrical conduit and wiring interconnections.

Thermally operated control shall consist of a hot spot temperature sensing relay with the thermal element mounted in a well and a bushing type current transformer. Energy from the current transformer shall be added to the highest oil temperature of the transformer to indicate the simulated hot spot condition in one phase of the transformer winding. The well shall conform to the requirements of IEEE C57.12.00 and C57.12.1.

A cooling system control scheme shall be provided to regulate fan operation, activate an alarm, and trip the transformer primary circuit. The control system shall utilize a multi-stage thermally operated relay. The contacts of the thermal relay shall be rated for 125 VDC. The control scheme shall include set-points to initiate the following actions depending upon cooling method.

- a. 1st Set-point: Energize the alarm contact of the thermal relay (OA) or energize the cooling fans (OA/FA).
- b. 2nd Set-point: Trip the transformer primary circuit (OA) or energize the alarm contact of the thermal relay (OA/FA)
- c. 3rd Set-point: Trip the transformer primary circuit (OA/FA)

The Contractor shall determine the applicable temperature for each set-point. If the Contractor requires set-points other than those listed above for proper operation of the transformer, the set-points shall be submitted, prior to calibration and test, for Review by the Contracting Officer.

Fan motors shall be 460 volt, three phase, and shall be supplied with starters incorporating thermal overload protection. Normal operation of the fan motors shall be with the thermally operated control system.

3.4.3.13 Transformer Control Panel: The transformer controls shall be in a NEMA 4X enclosure located on the side of the transformer at an enclosure height not greater than 72 inches above the concrete foundation. The Control Panel shall include cooling controls, fan starters, pressure and temperature indicators, alarm devices, current transformers, strip heater with thermostat, a 120 VAC light and receptacle, and other associated components. Power distribution and circuit breakers shall be provided for all accessories.

Included on the control panel shall be a manually operated bypass switch for fan operation and shall be connected in parallel with the automatic fan control contacts. The manual switch shall discretely and sequentially activate all fan sequences as outlined in the cooling system control requirements.

3.4.3.14 Enclosures: Enclosures shall be as required by NEMA for specific locations. Metallic materials shall be protected from corrosion. Equipment enclosures shall have the standard finish by the manufacturer. Aluminum shall not be used in contact with earth; and where connected to dissimilar metal, shall be protected by approved fittings and treatment. Ferrous metals such as structural steel, anchors, bolts, braces, boxes, washers and miscellaneous parts not of corrosion resistant steel shall be hot-dipped galvanized after fabrication, except where other equivalent protective treatment is specifically approved in writing.

3.4.3.15 Lifting and Moving Provisions: As a minimum, the transformer shall have the following built-in provisions for lifting and moving.

- a. Lifting eyes or hooks for the cover and tank.
- b. Lifting lugs for lifting complete transformer.
- c. Base designed for rolling and provision for pulling in direction of rectangular base centerlines.
- d. Jacking points at all corners of the transformer base.

3.4.3.16 Paint: Interior and exterior surfaces of all equipment shall be thoroughly cleaned by sandblasting, pickling/rinsing, etching, or other means as Approved by the Contracting Officer. Surfaces shall then receive, in a timely manner, a rust-inhibitive phosphatizing or equal treatment. All outside surfaces shall be primed, filled where necessary, and receive a minimum of two coats of exterior paint. The transformer, all associated cabinets, and hardware shall be painted light gray, FS 595, #16473.

3.4.4 FACTORY INSPECTIONS AND TESTS

As a minimum, factory tests of the input isolation transformer shall include:

- a. All applicable routine tests as identified by IEEE C57.18.10. As a minimum, these tests shall include resistance measurements of all windings, insulation resistance, applied potential, ratio tests, polarity test, phase relation test, no load losses at rated voltage, impedance voltage and load loss at rated current, and dielectric tests
- b. Sample and test oil in accordance with ASTM D3487
- c. Test instrument transformers in accordance with IEEE C57.13
- d. Simulate and verify operation of all cooling system modes, interlocks, and alarms

- e. Calibration of all instrumentation
- f. Verify functioning of all cooling fans, control circuits and instrumentation

3.5 HARMONIC FILTER

3.5.1 SCOPE

The Contractor shall design, furnish, install, and test a Filter Network for the Power Supply system. The filter network shall provide power factor correction and harmonic filtering as required by the Power Supply system.

3.5.2 PERFORMANCE REQUIREMENTS

The filter network shall meet or exceed the performance requirements described in this section.

3.5.2.1 Filter Network Rating: The filter network shall have sufficient rating to meet all requirements of this Specification. The filter rating and tuned frequencies shall be coordinated with the overall Power Supply design based on the harmonic and power system studies. The filter network shall impose no operational constraints on the Power Supply which result from power capacity, capacitor bleed down times, switching duty cycles, or other design or component limitation.

If any site measurements of the existing network impedance indicate the necessity to change the filter network impedance, the Contractor, at no additional cost to the Government, shall accomplish the change.

3.5.2.2 Filter Protection and Control: The filter network design shall be such that all necessary devices for fault protection, surge arresting, metering, control, line side and component disconnection, and personnel protection functions are provided.

An isolating device for line disconnection shall be provided.

Phase current transducers shall be provided.

Neutral point current balance monitoring and protection shall be provided.

A grounding switch shall be provided, including a pole for the capacitor bank(s) wye point.

Operation of the filter network shall be controlled by the Power Supply system controls.

The means to preclude the out of phase re-energization of filter network capacitors shall be provided.

3.5.2.3 Environmental Considerations: The filter network shall be designed and constructed to withstand the environmental surroundings where it is installed. Installation in an outdoor location is subject to the environmental conditions described at Langley Research Center, Hampton, Virginia.

Filter network components shall utilize non-toxic, biodegradable, synthetic insulating liquids to minimize environmental impacts due to leaks. The use of PCB type insulating liquids will not be permitted.

3.5.2.4 Reliability: The filter network shall provide commercial quality reliability with a design life of at least 35 years.

3.5.2.5 Maintainability: Routine maintenance of the filter network shall not exceed 12 hours a year by design. Self diagnostics and interlocks shall be incorporated into the filter network design and shall interface with the filter network controls to monitor and indicate malfunctions and alarms. Components that may require replacement, calibration, or maintenance shall be easily accessible without the use of ladders. The filter design shall be such that replacement or repair of any component does not require the removal of any other components from the filter. On large components, lifting provisions shall be provided to facilitate removal.

The Contractor shall provide a recommended spare parts list with costs, in order to minimize the mean-time-to-repair (MTTR). This shall be broken into two categories: 1) Parts required to keep the MTTR below 4 hours, and 2) Parts required to keep the MTTR below 24 hours.

3.5.2.6 Safety: The filter network shall be designed and constructed to meet all safety requirements of ANSI C2, IEEE 18, IEEE 519, IEEE 1036, NEMA ICS1, NEMA TR1, and NFPA 70. The equipment shall be in outdoor fenced or walled areas. The filter network design shall adhere to all clearance requirements for equipment with exposed energized parts or terminations. All non-current carrying components or supporting hardware shall be grounded.

3.5.3 HARDWARE REQUIREMENTS

3.5.3.1 Harmonic Filter Design and Construction: The Contractor shall provide a new harmonic filter to mitigate harmonic currents and provide power factor correction for the new Power Supply. The harmonic filter shall be designed, constructed, and factory tested in accordance with applicable ANSI, IEEE, NEC, and NEMA standards. The harmonic filter shall provide power factor correction as

required by the Power Supply. The harmonic filter shall consist of passive, three phase elements connected downstream of the Point of Common Coupling (PCC) to mitigate predictable characteristic harmonic frequencies, generated by the Power Supply, to acceptable levels as recommended by IEEE 519.

The components that comprise the harmonic filter, together with provisions for cable terminations and accessories, shall be assembled as an indoor rated system or outdoor rated system, based on the Contractor's design approach. The rated BIL level for the harmonic filter assembly shall not be less than 95 kV. Provisions shall be made to ground the enclosures and component support frames.

Current carrying conductors shall be copper.

A grounding switch shall be installed to ground all phase and neutral conductors of the harmonic filter. One ground switch is required for each circuit breaker that interrupts harmonic filter currents. A key interlock scheme shall be employed to force the harmonic filter breaker to be mechanically locked open prior to grounding the filter network(s). A timer interlock shall be used to prevent grounding, re-energization, and personnel access to the harmonic filter for a minimum of 10 minutes after opening of the circuit breaker. Two stainless steel termination pads at the base diagonally opposed shall be provided with a NEMA two hole (1/2"-13 UNC) pattern for external system ground connections.

Outdoor enclosures shall be rated NEMA 3R. Provisions for anchoring to a concrete mounting pad shall be provided. The bottom of the enclosure and the underside of the roof shall be coated with a heavy, rubberized, protective coating, a minimum of 1/32" thick. If a prepackaged enclosure is used for the harmonic filter, lighting, heating and cooling components shall be included, with appropriate power and control wiring, circuitry, and interlocks.

The Contractor shall design and supply the harmonic filter with sufficient instrumentation to monitor current flow in each frequency network. This current flow information shall be displayed on the Power Supply controls interface.

If the tuning reactors can sufficiently limit fault current to allow the filter breaker overcurrent detection to go un-tripped, additional relaying shall be provided to detect individual filter network faults and trip the filter breaker.

The harmonic filter shall be designed to have low impedance to the specific frequencies generated by the new Power Supply. The three phase branch circuit elements of the harmonic filter shall be tuned to the characteristic harmonic frequencies generated by the

solid-state motor control system, and shall comply with the following component specifications.

3.5.3.2 Capacitors: Capacitors shall be single phase, welded steel construction, hermetically sealed, and rated for voltages applied in the chosen bank configuration.

Each capacitor shall include two porcelain terminal bushings with copper studs, and an internal discharge resistor capable of draining residual capacitor voltage to less than 50 volts within 5 minutes after de-energization of the system.

Each capacitor shall be individually fused. The fuses shall be rated to isolate a faulted capacitor from the remaining bank, while protecting the remaining capacitors from damage. The fuses shall be rated to carry the maximum continuous current plus 15% margin.

Each capacitor bank shall be designed such that, upon failure and isolation of a single capacitor can, the voltage upon the remaining cans does not exceed the continuous rating. In addition, the bank must withstand the failure and isolation of a second capacitor can for 5.0 seconds until the bank is disconnected.

Each capacitor shall contain completely biodegradable, non-flammable, non-PCB dielectric fluid. The dielectric shall be capacitor grade nonmetalized polypropylene film.

Capacitors shall be switch rated, with the following minimum ratings:

Design Life:	200,000 hours
End of Life Capacitance:	97% of rated value
Switching Cycles:	200,000 cycles

The Contractor shall design the filter elements to use the fewest number of individual capacitors as possible, while maintaining the same KVAR unit rating. Capacitors shall be individually fused and provided in bank configurations that allow monitoring of phase unbalance voltage or current. The phase unbalance shall be detected using protective relaying devices that alarm at greater than 4% unbalance between phases, and trip at greater than 6% unbalance between phases. Balanced bank configurations using a split star connection shall be used to provide in phase capacitor failure detection by neutral point current balance.

3.5.3.3 Reactors: Reactors shall be single-phase, air-core type or iron-core type designed and constructed to withstand available fault currents. Iron-core reactors shall be air-gapped, with bolted construction, using transformer grade steel. Laminations shall be braced to prevent audible noise due to vibration. Reactors shall be mounted on station post type insulators to

support the unit weight, and be spaced to minimize magnetic field interaction from the structure and adjacent reactors. Vibration proof assembly and mounting hardware shall be used to prevent loosening.

Reactor windings shall be vacuum-pressure impregnated with a 220 degree C insulation system or equal. The maximum temperature rise at rated duty shall not exceed 115 degrees C over a 40 degree C ambient temperature.

Winding conductors shall be sized for fundamental and harmonic currents, including skin effects and hysteresis losses. The reactors shall be designed for operation at 115% of the nominal filter phase to ground voltage.

Reactors shall be provided with a minimum of three fully rated taps that allow the individual inductance to be adjusted above and below the nominal inductance.

Each reactor shall be equipped with a thermal overload instrument or detector connected to an alarm contact in the Power Supply control system.

3.5.3.4 Resistors: Resistors, if required, shall be single phase, stainless steel ribbon type, air cooled, with stainless steel enclosures, louvered to allow air circulation. Resistors shall be mounted external to the filter enclosure, with raintight openings for connections and air circulation.

Resistor tolerance shall be +/- 5% or better. Resistance tolerance between phases shall be +/- 1% or better.

Resistor continuous current rating shall be a minimum of 1.5 times the working current level.

3.5.3.5 Relaying: The harmonic filter shall be supplied with sufficient protective relaying and instrumentation to monitor the current flow in each of the tuned elements. Relaying shall be provided to detect individual tuned element faults (overcurrent, inverse time overcurrent, and ground fault, as a minimum) and provide a signal to trip the protection breaker.

3.5.3.6 Disconnecting Devices: The filter shall incorporate a circuit breaker(s) to provide isolation, overload, unbalance, and fault protection of the filter network. Solid state switching devices will not be permitted. Devices shall be designed for the duty cycle imposed by the new Power Supply configuration. If existing components are used, the Contractor shall determine the suitability for switching the required capacitive currents, and shall be responsible for circuit breaker compatibility.

3.5.4 FACTORY INSPECTIONS AND TESTS

The Contractor shall perform factory inspections and tests in accordance with applicable industrial standards and codes, the manufacturer's standard practices, and the Contractor's Quality Assurance Plan. As a minimum, factory tests of the harmonic filter shall include:

- a. Capacitors shall be tested for unit capacitance value at 60 Hz and insulation resistance
- b. Reactors shall be measured for DC winding resistance, and full load thermal losses calculated and submitted with test data.
- c. Reactor inductance shall be measured at 60 Hz.
- d. Reactors shall be tested for voltage withstand using a high potential test set
- e. Control circuits, interlocks, and protective devices shall be checked for proper operation
- f. Cooling and heating power and control circuits shall be checked for proper operation
- g. Operation of grounding switch, interlocks and Kirk key sequences

3.6 Power Supply

3.6.1 SCOPE

The Contractor shall design, manufacture, test, furnish, and install a static converter Power Supply to provide the proper voltage and current to the arc-heater. The Power Supply shall be designed to accept power from the new input isolation transformer transformer.

3.6.2 PERFORMANCE REQUIREMENTS

The Power Supply shall meet or exceed the performance requirements described in this section.

3.6.2.1 Power Supply Rating: The Power Supply shall have sufficient ratings to meet all requirements of this Specification.

3.6.2.2 Harmonic Distortion: The Power Supply and its associated harmonic filtering system shall not cause voltage and current distortion, telephone influence factor (TIF) and voltage fluctuation at the Point of Common Coupling (PCC) that exceed the limits recommended by IEEE 519. The Contractor shall make

verification measurements at the PCC with currently calibrated measurement devices approved by the Contracting Officer. The Contractor shall be responsible for taking all measurements, verifying supply capacity, and providing all equipment, filters, and analysis to determine if, and what quantity of harmonic filtering is required to meet the limits of harmonic distortion specified herein.

3.6.2.3 Fault Protection: The Power Supply shall be designed and braced to withstand the maximum currents available under fault conditions. The fault current available at the PCC is given in Appendix C. An electrical open circuit or short circuit at the arc-heater terminals shall not cause any damage to the transformer, filter network, or Power Supply.

3.6.2.4 Reliability: The Power Supply shall provide commercial quality reliability with a design life of the Power Supply, associated hardware, filters, reactors, and cooling systems of at least 35 years.

3.6.2.5 Maintainability: Routine maintenance of the Power Supply shall not exceed 24 hours per year, by design. Self-diagnosis and interlock alarms shall be designed into the Power Supply controls to monitor and indicate malfunctions. Components that may require replacement, calibration, or maintenance shall be easily accessible through doors, or removable panels. Mounting methods and fasteners shall provide for rapid and unobstructed removal and replacement of devices. The Contractor shall provide a recommended spare parts list with costs, in order to minimize the mean-time-to-repair (MTTR).

3.6.2.6 Safety: The Power Supply shall be designed and constructed to meet all safety requirements of NEMA ICS 3.1 and NFPA 70. All equipment shall be in grounded metal enclosures or fenced areas with no exposed energized parts or terminations. Maintenance access doors shall be provided. All access doors shall have provisions for padlocks to exclude unauthorized personnel. Interlock switches shall be employed where required to protect maintenance personnel. A mechanism to provide air gap isolation and grounding of the arc heater shall be included. All non-current carrying components or supporting hardware shall be grounded.

3.6.3 HARDWARE REQUIREMENTS

The Power Supply shall be complete with all power components, enclosures, wiring, software, and control system. The Power Supply shall meet or exceed the hardware requirements described in this section.

3.6.3.1 Power Supply Design and Construction: The Power Supply shall be of the static type, and shall contain identical rectifier

bridges. The Power Supply shall be completely solid state, and shall be microprocessor controlled. All controls, interlocking, and diagnostic monitoring shall be integrated into digital logic that shall be hardwired or coded into a non-volatile configuration. The basic design and construction of the Power Supply shall include the following:

- a. The Power Supply control shall be designed to ensure smooth, automatic ramping of the gate firing control to each thyristor.
- b. The Power Supply shall be designed for a minimal amount of field connections.
- c. Where internal connectors are used, they shall be different sizes, types, or uniquely keyed by function such that no improper insertion combinations are allowed. All connectors, racks, slots, cubicles, and components shall be individually marked, and located on system drawings to allow efficient location and troubleshooting of devices.

3.6.3.2 Medium Voltage Connections: Medium voltage bus and terminal connections shall be as follows.

- a. All internal, interconnects shall be made with copper bus bars. Bus bars shall be welded where feasible. Silver or tin plated joints with bolts and lock washers shall be used where welding is not feasible.
- b. All power terminals shall be provided with multi-grip, compression type terminal lugs. The lugs and terminal spaces or cabinets shall be designed for cables or buses to carry the rated ampacity of the Power Supply.
- c. The DC bus system shall connect to the AHSTF arc-heater isolation disconnect switch and at the new power supply

3.6.3.3 Low Voltage Connections: Low voltage bus and terminal connections shall be as follows.

- a. All low voltage wiring between subcomponents and devices within or on equipment enclosures shall be completely installed and verified, and appropriate circuit points shall be wired to barrier type terminal blocks for equipment interconnections. The blocks shall have 10 percent of the terminal points reserved as spares for future use.
- b. All interconnecting wiring shall be contained within the Power Supply enclosures. No external wireways, conduits, or connections shall be permitted between enclosure sections. For connections between major components, suitable wiring

methods shall be employed, appropriate with the voltage and ampere rating of the interconnections.

- c. Low voltage wiring located in medium voltage compartments shall be surrounded by a suitable metal barrier.
- d. Wiring internal to all compartments not otherwise enclosed in conduit or ducts shall be bundled together and routed vertically and horizontally throughout the enclosures.
- e. Hinge wire shall be provided with a droop loop that allows rotation around the longitudinal axis of the conductors.
- f. Terminations shall be made with ring tongue or spring spade, crimped lug terminals, or other approved method. In-line conductor splices shall not be used.

3.6.3.4 Ground Bus: All compartments and enclosures shall be provided with a copper ground bus. This bus shall be connected to the ground bus in adjoining compartments or enclosures. This ground bus shall serve as the ground source to which the enclosure, circuit neutrals, shields, conduit, and non-electrified metal parts are solidly connected.

3.6.3.5 Thyristor bridges: Thyristor bridges shall be designed and constructed to comply with IEEE and the following criteria.

- a. Thyristor bridges shall be phase controlled, solid state units, based on N+1 design. Their design shall be coordinated with that of the input isolation transformer and the heater such that proper turn off and turn on operation can be achieved on the line and load sides.
- b. The thyristor bridge sections shall be of duplicate construction, and provided with surge protection between the input isolation transformer and converter bridges. Thyristors and heat sinks shall be arranged such that an individual thyristor can be removed and replaced in 30 minutes or less with tools provided by the Contractor. Maintenance access shall be provided in the enclosure compartment and thyristor stack such that no additional climbing equipment shall be required by maintenance personnel to change out any thyristor or associated circuit component.
- c. The thyristor bridges shall be able to withstand a three phase short circuit current until interrupted by the new supply breaker.
- d. For series connected thyristor devices, when one thyristor per stack fails shorted, the repetitive, peak inverse blocking voltage margin shall not be less than 2.25 per unit

referred to the instantaneous maximum value of the fundamental wave at 110 percent of line voltage. Thyristor Breakover Device (BOD) monitoring shall be provided. The thyristors shall be fuseless.

- e. All thyristor circuits shall be designed to coordinate with peak voltage protecting snubber networks, and with di/dt and dv/dt networks such that the power supply can operate continuously with one thyristor failed shorted in each bridge leg.
- f. Each series connected thyristor shall incorporate a separate fiber optic circuit for monitoring the condition of the thyristor in the "On" and "Off" states. These fibers shall be compiled into a thyristor monitoring system which will indicate and announce a specified failure of a thyristor. This thyristor monitoring system shall be fully integrated with the Power Supply control microprocessor for firing, data logging, and interlocking functions.
- g. Each thyristor shall incorporate fiber optic or magnetic trigger circuits for high voltage isolation. Fiber optic circuits shall be continuously monitored by the thyristor monitoring system. Redundant fiber optic firing cable shall be included.
- h. The operating temperature of the thyristors shall not exceed 80 percent of maximum continuous junction temperature under rated conditions. Under fault conditions, the thyristor junction temperature shall not exceed the thyristor manufacturer's catalog data.

3.6.3.6 Trigger Power Supply: A trigger power supply shall be provided to reliably ionize the gas in the arc-heater at the beginning of a run and shall have the following features:

- a. A high resistive internal impedance
- b. Provide a high voltage, radio frequency supply at minimum current for a short time while connected in parallel with the main power supply.
- c. Operation of the trigger supply shall be incorporated as an automatic function at the initiation of the Power Supply operation. It shall be of sufficient voltage and duration to initiate an arc.
- d. A manual operation mode shall be provided to check the operation of the trigger supply.

The Power Supply shall also be capable of operating in a backup trigger mode. This shall consist of the existing consumable

electrode installed in the arc heater that melts once the Power Supply is energized, thereby initiating the arc.

3.6.3.7 Current Regulator: The Power Supply current regulator shall have at a minimum, the following characteristics:

- a. The current regulator shall maintain stable control within the performance tolerance in Section 3.1.2.4 at all points within the operating envelope. Regulator design shall take into account negative dynamic resistance and rapid, random variations in voltage, which are characteristic of an electric arc.
- b. The current regulator shall accept a current setpoint from the serial link, a remote 4-20 milliampere signal, or from a current setpoint control on the local control panel.
- c. Automatic gain control shall be provided.

3.6.3.8 Instrumentation and Control: The instrumentation and control system shall consist of all Power Supply regulation and interface circuitry integrated with all sensing, control, protective, displaying, and recording devices necessary to provide a complete and operable Power Supply as required by this Specification.

The Power Supply controller shall be comprised exclusively of modular, standardized, solid state components on plug-in printed or uniquely keyed preassembled circuit boards of industrial standard manufacture. The printed circuit cards shall be treated in accordance with standard commercial practices to protect the cards from moisture and vibration. The power supply control shall be mounted in freestanding cubicles, using standard equipment frames with easily accessible front and rear sides. Assembled cubicles shall be factory wired to connectors in the bottom or rear of the cubicles for interface to other components. The control system shall be a self-contained, user friendly, digital controller, tuned to provide optimal and repeatable Power Supply performance.

The microprocessor controlled equipment shall be specifically designed for power conversion applications. The system shall have a minimum of two years operating experience in comparable Power Supply configurations. Prototype hardware or alpha/beta power supply control software shall not be used. The operation of the Power Supply, routine changes of parameters, and the use of built-in diagnostic and monitoring programs shall not require the knowledge of any programming languages. The Power Supply control functions shall be upgradeable as technology advances to modify, enhance or optimize sequence or control characteristics.

The Power Supply controller shall incorporate a serial interface. A portable computer shall be provided as part of the Power Supply to configure the Power Supply parameters. This shall include all tuning variables, software I/O instruction sets, and monitoring capabilities. In addition, data transfer capability such as copy to/from disk, and printing options shall be included. The computer shall have the capacity to access the Power Supply fault history, whether the power supply is on or off-line, and display or print the fault history record.

The Power Supply controller shall include a local control panel. The control panel shall have a sufficient set of operator interface devices to allow commissioning, troubleshooting, and independent control. As a minimum the following devices or functions shall be provided on each panel.

- a. Indicators and switches shall be provided for the following functions.
 - 1. Converter Power On and Off
 - 2. Output Current Start and Stop
 - 3. Local and Remote Control Select
 - 4. Breaker 3085 Trip and Reset
 - 5. Trigger Supply Select: Auto, Off, Manual, and On,Off
- b. Indicators shall be provided for each of the following functions.
 - 1. Power Supply Operating
 - 2. Power Supply Fault
- c. Engineering units displays shall be provided for the following functions.
 - 1. Incoming power supply line voltage, phase current, megawatts, and megavars
 - 2. Direct voltage and current to the arc-heater
 - 3. Cooling water pressure, flow, conductivity, and temperature

The controller shall provide, as a minimum, the following control functions. The controller shall smoothly transition from one function to another.

- a. Starting and Stopping - This shall be the sequence used to bring up the Power Supply from a non-energized state prior to gate commanded thyristor firing and back down to a de-energized state.
- b. Running - This shall be the loaded mode for the Power Supply. The control system shall incorporate similar

ramping up/down features to allow continuous adjustments of power to the load.

The Power Supply controller shall have available function generator type ramping profiles including s-curve, cubic, sine, and programmable continuous and discontinuous piece wise linear functions to allow best fit of the arc establishment profile.

The controller processor shall incorporate an independent, hardwired, watchdog circuit that monitors the processor scan function, and trips in the event the processor stops.

Hardwired protection circuits shall be provided for overcurrent, overvoltage, phase imbalance, and watchdog trip. These shall be implemented with precision (less than 1 percent tolerance) components. Adjustable resistors shall not be used in these circuits.

The power supply controller shall monitor the following signals, as a minimum, and shall provide the indicated action. All fault codes or annunciations shall be in English language. Symbols or abbreviations shall not be used. When a fault occurs, the subsequent alarms/trips may mask the initial event. Therefore, the power supply controller shall have a first fault feature that incorporates a memory circuit to identify the first event of fault annunciation.

a. Alarms: The following signals shall indicate a Power Supply alarm.

1. Coolant low level
2. Thyristor Failure
3. Heat exchanger leak
4. Trigger fault

b. Alarm and Trip: The following signals shall indicate a Power Supply alarm and initiate a power supply trip or shutdown.

1. Processor Watchdog Failure
2. Input or Output Rack Fault
3. Source side Undervoltage
4. Source side Overvoltage
5. Source Phase Reversal or Loss
6. Commutation Failure
7. Ground Fault
8. Gating Supply Failure
9. Coolant high temperature
10. Coolant loss of flow
11. Coolant loss of pressure
12. Coolant high conductivity
13. Enclosure Doors open
14. Low Control Voltage

- 15. Blown Fuse
- 16. Protective Relaying Trip

3.6.3.9 Diagnostics and Troubleshooting: The Power Supply controller shall have self contained, user-friendly, diagnostic capabilities to continuously monitor the Power Supply system for faults, provide pre-operational system checks before the Power Supply is started, and provide extensive off-line troubleshooting.

The controller shall provide features to allow technicians to rapidly locate faults after an alarm has occurred and to monitor the proper function after the problem has been eliminated.

The controller shall provide a minimum of eight, 16 bit resolution analog output channels that can be configured through the controller software to output any Power Supply parameter. Initially the channels shall be configured 0-10 volts with the following signals in appropriately scaled engineering units:

- a. Power Supply Output voltage
- b. Power Supply Output current Actual
- c. Power Supply Thyristor firing angle
- d. Power Supply Input phase voltage
- e. Power Supply Input phase current
- f. Power Supply Output current Setpoint
- g. Power Supply Cooling Water Temperature
- h. Power Supply Harmonic Filter RMS phase current

The controller shall include complete capability to perform built-in off-line test programs for the following functions:

- a. Local mode operation
- b. Gate Firing System
- c. Thyristor Bridge Functionality
- d. I/O simulation
- e. Cooling system operation

These test sequences shall be activated without additional software programming or modifications. The controller shall be capable of performing all troubleshooting at low (<480 VAC) or no

voltage levels, and shall contain all hardware and software to exercise thyristor bridge circuits at low voltage levels.

3.6.3.11 Tunnel Controls Interface: The Power Supply shall interface to the existing facility controls and Programmable Logic Controller (PLC). The Contractor shall provide the following interfaces, complete with all hardware:

a. A communications link consisting of all software, hardware, and cabling from the Power Supply controller to the existing facility PLC. The existing PLC is an Allen Bradley ControLogix™ platform and the communication link format shall be ControlNet™. For this link, the Contractor shall provide all hardware, including one Allen Bradley PLC ControLogix module, #1756-CNB. Status data, signal values, and alarm/trip conditions shall be communicated to the PLC from the Power Supply. The PLC shall communicate to the Power Supply operational commands, mode configuration requirements, and a current setpoint.

b. Hardwired connections between the Power Supply and the facility PLC shall be determined as the design phase of the Power Supply is finalized. As a minimum it shall consist of an Emergency Stop circuit, analog input current setpoint, local/remote status, and start/stop functions. The Contractor shall be responsible for all wiring, conduits, and installation to the facility control room.

3.6.3.12 Enclosures: The Power Supply shall be fabricated with a suitable enclosure to meet all safety and environmental conditions of the equipment. The Contracting Officer shall have approval of the final Power Supply arrangement and enclosure. Enclosures shall be as required by NEMA for specific locations, unless otherwise indicated in this Specification. Metallic materials shall be protected from corrosion. Equipment enclosures shall have the standard finish by the manufacturer. Ferrous metals such as structural steel, anchors, bolts, braces, boxes, washers and miscellaneous parts not of corrosion resistant steel shall be hot-dipped galvanized after fabrication, except where other equivalent protective treatment is specifically approved in writing.

The enclosure shall be supplied with ambient outside filtered air exchange using screens, filters, ductwork, and blowers.

Each enclosure compartment shall include an interior light controlled by a door-activated switch, (1) 15 amp, 120 vac service receptacle, and space heater(s) thermostatically controlled, sized to prevent condensation within the cubicle.

3.6.3.13 Identification and Marking: Identification plates shall be of stainless steel. The primary Power Supply nameplate shall contain the manufacturer's name and address, model number, serial

number, operational information and limits, weight, and connection diagrams. Lettering shall not be smaller than 0.25". Any other pertinent information such as instruction manual designations, drawings, and patent information shall also be provided in a like manner. Nameplates shall be firmly attached to the equipment with nonferrous rivets or similar connections to prevent loss or removal. All information shall be engraved or embossed to ensure that data can be retrieved after exposure to environmental and/or accidental conditions. Circuits rated 480 volts and above shall comply with the Occupational Health and Safety Agency Standards for warning signs locations.

Identification of secondary devices, enclosures, and wiring, shall all be affixed with permanent tags. No tag shall be smaller than 0.75 inches high by 2.0 inches long. Lettering shall not be smaller than 0.125". Where applicable, information plates shall be attached by corrosion resistant methods. Hand lettering, ink marking, and embossed, self-adhesive tapes or tags are unacceptable.

The Contractor shall indicate on drawings and in manuals a logical and consistent method of identifying each major component, enclosure, and device used in the Power Supply. This method shall be incorporated into all documentation drawings, instruction, maintenance, and troubleshooting manuals. This method shall be implemented on actual hardware by the means described below. If the Power Supply is disassembled to facilitate the Contractor's shipping plan, all re-assembly, internal interconnection, and energization of the Power Supply circuits shall be the sole responsibility of the Contractor.

3.6.3.14 Paint: Interior and exterior surfaces of all equipment shall be thoroughly cleaned by sandblasting, pickling/rinsing, etching, or other means as approved by the Contracting Officer. Surfaces shall then receive, in a timely manner, a rust-inhibitive phosphatizing or equal treatment. All outside surfaces shall be primed, filled where necessary, and receive a minimum of two coats of exterior paint. The Power Supply, all associated equipment, and hardware shall be painted per manufacturer's standard color.

3.6.3.15 Cooling: The Contractor shall provide a cooling system for the Power Supply. The Power Supply shall be water cooled.

For water to water heat exchangers, they shall be designed and provided to connect to the Government's existing cooling water system. Water analysis data is provided in Appendix B. All connection flanges, valves, regulators, and piping shall be part of the Power Supply cooling system. The cooling system shall be sized to prevent the thyristor junction temperature from exceeding the maximum thyristor junction temperature permitted by the thyristor manufacturer under all operating conditions including fault conditions.

The Power Supply cooling system shall provide redundant pumps. The cooling system pumps shall be electrically powered from different branch circuit breakers. The cooling system shall provide operation of the pumps such that one pump acts as the operational pump and the other pump remains in stand-by mode. Upon detection of a fault in the operational pump, the system shall automatically and immediately switch over to the stand-by pump. Either pump shall be able to act as the operational or stand-by pump. This mode of operation shall apply to all components for which redundancy is provided.

The system shall include a flow sensor which shall initiate an alarm for loss of flow. The cooling water temperature shall be monitored to initiate an alarm if cooling is reduced to the point that the Power Supply cannot operate at 100 percent rated output. In addition, a shutdown shall be initiated prior to any thermal damage to thyristors, resistors, capacitors, inductors, or any other device, which may incur a shortened life expectancy from overheating.

The closed loop cooling system shall use de-ionized water provided by the Contractor. The cooling system shall have the capacity and all components to maintain the resistivity of the de-ionized water for safe operation of the Power Supply. No ethylene glycol mixtures shall be used. The cooling system shall utilize high grade stainless steel pipe or high quality plastic tubing. All water system connections shall be made with glued, brazed, ferrule compression fittings, or approved equal. No worm screw clamps shall be used. Thyristor stack assemblies shall be designed such that thyristors can be exchanged without breaking and making water system connections.

3.6.3.16 Electromagnetic Interference Control: The Power Supply shall be provided with the necessary filters to limit the conducted electromagnetic interference from entering the incoming and outgoing power and control lines. The Contracting Officer shall be provided with the designed emission figures and/or certifications of previous approval by the Federal Communications Commission and any other government agencies.

The Power Supply shall be provided with the necessary shielding, screening, and metal enclosures to attenuate the radiated electromagnetic interference to levels that will not affect sensitive electronic and communications systems outside the physical boundaries of the Power Supply equipment. The Power Supply shall also be protected against radiated electromagnetic interference from external sources.

Suppression of electromagnetic interference shall be accomplished to within the limits recommended in IEEE C63.12. The Contractor

shall take readings around the perimeter of the Power Supply during operation to verify the level of electromagnetic emissions.

3.6.4 FACTORY INSPECTIONS AND TESTS

The Contractor shall assemble the Power Supply and perform factory and on-site inspections and tests in accordance with the applicable industrial standards and codes, the Contractor's or manufacturer's standard practices, and the Contractor's Quality Assurance Plan.

Factory inspections and tests of the Power Supply shall include:

- a. Test thyristors as required by the manufacturer.
- b. Test thyristor bridges in accordance with IEEE 444.
- c. Test thyristor firing circuits in accordance with manufacturer's quality assurance program.
- d. Test instrument transformers in accordance with IEEE C57.13.
- e. Simulate and verify operation of all cooling system modes, interlocks, and alarms.
- f. Calibrate all instrumentation.
- g. Test all microprocessor controller circuit boards, as appropriate, for the following functions.
 1. Power Supply tolerances.
 2. Logic manipulation and clock speed.
 3. Input/output points.
 4. Analog to digital and digital to analog conversion rates and accuracies.
 5. Serial interface protocols.
 6. Non-volatile RAM manipulation.
- h. Simulate and verify conformance of all alarm and trip points in software and hardware.
- i. Inspect and test switchgear, disconnects, and circuit breakers prior to energization. Protective relays shall be set, calibrated, and settings verified to operate in accordance with the manufacturer's time-current curves.

3.7 Switchgear: The Power Supply shall be fed by an appropriate section of switchgear to provide isolation, and overcurrent protection to the transformers, harmonic filters, and power supply. The switchgear shall replace the existing air switch 3084 and the existing breaker 3085, and contain at least one air switch

and one breaker in the configuration of the existing switchgear. The air switch shall close into load side grounding fingers when opened. The switchgear shall be a totally enclosed, metal clad outdoor rated assembly that shall contain all required equipment to operate and protect the downstream components. The switchgear shall comply with IEEE C37.20.1, NEMA SG5, and the following criteria.

- a. If more than one breaker is required, all breakers shall be identical and shall comply with NEMA SG4.
- b. Breakers shall be three pole, vacuum or Sulphur-Hexafluoride (SF6), with current ratings as required. The breakers shall be horizontal draw out units.
- c. The operating mechanism shall be of the stored energy type utilizing a spring charged by a universal type motor. The mechanism shall consistently close the breaker after a close command has been given. The mechanism shall be provided with a position indicator which gives positive indication of whether the breaker is open or closed.
- d. The power source for closing and tripping the breaker shall be 125 VDC, and shall be obtained from the existing source.
- e. The breakers shall be provided in rugged frames with wheels for withdrawal from the enclosure and rolling across the floor. A front panel shall be provided on the frame to shield personnel from high voltages when the enclosure door is open. The panel shall be removable for access to components when the breaker is out of the enclosure.
- f. Each breaker shall have the following auxiliaries installed:
 - 1) Primary and secondary disconnect contacts for breaker withdrawal.
 - 2) At least six spare electrically independent, single pole, auxiliary contacts which can be readily changed between form "a" and "b" configuration. These contacts shall be in addition to any contacts required for control, indicating lights, interlocks, and operation.
 - 3) Breaker operation cycle counter.
 - 4) Contact wear gap indicator requiring no tools to determine available contact wear.
- g. Switchgear compartments shall be completely wired with cable terminals, cable clamps, control bus, control power switch, and terminal blocks. Terminal blocks shall be readily

accessible for the external connections of metal-clad switchgear.

Low-voltage wiring for controls and accessories shall be run to terminal blocks having numbered points to identify circuits. Low voltage wiring shall be run in conduit or wiring raceways to isolate the wiring from high-voltage circuits. Wiring connections shall be identified.

Each compartment of the switchgear assembly shall be identified by an identification plate engraved with circuit function and function designations.

Removable elements of the same type and rating in the switchgear assembly shall be physically and electrically interchangeable in corresponding compartments. Front-hinged panel shall be suitable for mounting instruments, relays, control switches, and indicating lamps.

Barriers between a sectionalized bus with bus sectionalizing breakers in a compartment shall be sheet steel not less than 11 gauge. Other covers, barriers, panels, and doors shall be not less than 14 gauge. Each compartment shall be reinforced with structural members and welded together. Welds shall be ground to a smooth flat surface before painting.

A motor-operated position-changing mechanism shall be provided that will move the breaker between the test and operating positions by means of a levering device. Interlocks shall be provided to prevent the complete withdrawal of the circuit breaker from its compartment when the stored-energy mechanism is in the fully charged position. Circuit breakers shall be designed to prevent the release of stored energy unless the mechanism is fully charged.

The mechanical interlocks shall render the breaker mechanically and electrically "trip free" during withdrawal to the test position, or during removal, with direct-current potential trip coils of the voltage indicated, auxiliary switches, latch-checking switches, control relays, and operation counters.. The interlocks shall also prevent withdrawal of a closed breaker, prevent closure between test and operation positions, and prevent removal when the operation spring is charged. The shutters shall automatically cover the stationary primary disconnect contacts to prevent accidental contact with live terminals when the breaker is withdrawn. The shutters shall automatically open when the breaker is moved into the operating position.

A positive means to assure that breaker frames are grounded in the operation position, and during withdrawal and insertion shall be provided. A continuous rigid copper ground bus shall extend throughout the entire assembly and shall ground the stationary structure and equipment. Ground bus shall be capable of carrying the rated short circuit current of the protective devices in the switchgear assembly for a minimum period of one second.

The following local controls and indicators for each breaker shall be provided: Knife switch and fuses for the 125 VDC control power; Local test control switch, which shall be effective only when the breaker is in the test position; Red and green indicating lights to indicate whether the breaker is open or closed; The red light shall be connected to indicate trip circuit continuity; A mechanical device to indicate when the breaker is in the operating position and when in the test position.

Provide a space heater with thermostatic control for each breaker compartment to inhibit condensation of moisture.

- h. Switchgear assemblies shall be completely bussed utilizing electrical grade, high conductivity, insulated solid copper bus bar having a rectangular cross section. Main, riser and bus tap connections shall be uniformly positioned and phase sequenced in accordance with IEEE C37.20.1. Busses shall be supported and braced to withstand both electrically and mechanically the short circuit current ratings.

Termination and connection points of all bus bar in the switchgear shall be tin or silver plated by an electroplating process. Silver or tin coating methods that do not use the flow of electric current as part of the process shall not be acceptable. After plating the contact surface shall not be sanded or otherwise abraded, but shall be cleaned with a soft cloth immediately prior to final assembly.

All bus bar connections shall be made using silicon bronze bolts with wide flat silicon bronze washers under the bolt head and nut. These connections shall be tightened and checked by use of a calibrated torque wrench. Other connection designs may be used with the Approval of the Contracting Officer.

Main and auxiliary control draw out type connections shall be silver-to-silver contact, positive pressure, self-aligning, with enclosure-to-enclosure stationary mechanism when breaker is in the draw out position.

- i. The switchgear shall be provided with a terminal compartment for each bus and for each breaker.
- j. Potential transformers (PT's) shall be mounted on draw out carriages in a separate switchgear compartment. The high voltage terminals shall be disconnected and grounded when the carriage is withdrawn. Primary current limiting fuses capable of interrupting a short circuit shall be provided on the carriage. The potential transformers shall comply with IEEE C57.13.
- k. Current transformers (CT's) shall comply with IEEE C57.13 and shall have a suitable means of grounding the frame.
- l. The switchgear and auxiliary equipment shall be stationary mounted in self-supporting, self-contained, sheet metal enclosures with maintenance aisle and front and rear hinged doors. Sheet metal compartments shall be joined together to form a continuous structure. Sheet metal barriers, enclosures, and external covers and doors shall be constructed from cold-rolled carbon steel sheets of commercial quality not less than 14-gauge, with stretcher-level flatness in accordance with ASTM A366/A 366M.

Unit sheet metal shall enclose one or more vertically mounted power circuit breakers or auxiliary equipment in individual sheet metal compartments and a full height rear compartment. Housing shall be approximately 90 inches high with individual ventilated front and rear-hinged panels and bolted top covers. Rear compartment shall contain the main bus, main bus-tap connections, cable connections, and instrument transformers.

Access doors shall be flanged and shall close against rubber or similar gasketing material. Ventilated openings shall be provided with filtered covers and screened vents for protection against the weather and insects. Doors shall be equipped with latch, stops, and door locking mechanism.

Roof section shall be unit construction with removable sloping cover and overhanging roof drip edge. Base section shall be unit construction and shall support metal-enclosed switchgear six inches above the concrete foundation.

Switchgear enclosures shall include a removable steel floor plate which shall be drilled for conduit and cable during installation. Floor and roof of the switchgear shall be undercoated with a heavy rubberized protective sealing material at least 1/32-inch thick.

- m. Switchgear accessories shall include the following.

1. Closing lever for manually closing the circuit breakers outside the compartment, manually charging the breaker closing spring, and manually opening the shutter.
2. Breaker lifting yoke for attachment to breaker for lifting on or off compartment rails.
3. Transport dolly for moving breaker about outside its compartment.
4. Set of rail clamps for clamping breaker on extended rails for maintenance.
5. Mobile lift for lifting the breakers on or off the rails.
6. Set of test plugs for use with relays and meters.
7. Complete set of all special wrenches and tools required for the installation, maintenance, and repair of the switchgear.
8. Portable test cabinet and protective device test set for testing breaker trip settings vs. tripping times.
9. Removable hand crank for operating the levering in device, or breaker elevating crank handle.
10. Complete set of original manufacturer's time/current characteristic curves for all protective devices plotted on 11 x 17 inch tracing paper or provided in software format.
11. Kirk locks and transfer blocks to provide a safe sequence of deenergization and access to the air switch compartment, breaker compartment, harmonic filter, and power supply access.

3.8 SITE CONSTRUCTION

3.8.1 SCOPE

The Contractor shall provide all site construction engineering, plans, materials, equipment, and labor to install the new AHSTF Power Supply. Site construction shall include:

- a. Demolition of existing equipment as specified on the Contract drawings.
- b. Unpacking of Power Supply equipment.

- c. Assembly and installation of Power Supply equipment.
- d. Modifications to the existing cooling water system.
- e. Building modifications.
- f. Equipment connection and set-up.
- g. Tunnel interface connections and diagnostic systems.

The Contractor shall arrange to relocate the Project Office personnel as required, to the site once construction activities begin. This shall include the Program Manager, Project Manager, and Project Engineers. Project Field Superintendent, Field Engineers, QA Inspectors, and all support personnel required to operate and maintain the site office shall remain onsite on a continuous basis.

The Contractor shall submit a site plan drawing prior to mobilization showing intended temporary office and storage trailer locations and required laydown areas for approval by the Contracting Officer.

3.8.2 GENERAL REQUIREMENTS

3.8.2.1 Construction Specifications: In addition to the requirements of this Specification, all construction activities at NASA Langley Research Center shall incorporate materials, equipment, and methods as described in Attachment A, Construction Specifications. The Contractor shall utilize the applicable sections of the Construction Specifications based upon the final system design as defined by the Contractor's drawings.

3.8.2.2 Government Construction Manager: A Government Construction Manager will be assigned to oversee the site construction of this project. The Government Construction Manager will coordinate site use; monitor and inspect demolition, salvage, and construction activities; monitor site safety; and assist with the resolution of administrative issues or actions.

3.8.2.3 Protection of Equipment and Facilities: The Contractor shall protect existing facilities, equipment, and property from damage during the site construction work. Protection shall include, as a minimum, dust and dirt protection for the surrounding equipment, and electrical gear. The interiors of the building areas where construction work is being performed, and all equipment to be salvaged or re-used shall be protected from weather at all times. Equipment and property damaged as a result of the work shall be repaired or replaced by the Contractor.

Protective measures shall be taken to control accumulation and migration of dust and dirt in all areas of work. Adjacent

structures and equipment shall be cleaned of all dust, dirt, and debris caused by construction operations. All adjacent areas shall be returned to the condition existing prior to the start of the work, or as otherwise directed by the Contracting Officer.

Construction work shall be conducted so as to prevent damage to personnel, adjacent buildings, structures, and other facilities by falling debris or other causes. The Contractor shall promptly repair damage to equipment or facilities caused by construction work.

3.8.2.4 Temporarily Relocated Material and Equipment: The Contractor may temporarily relocate existing equipment, materials, or other Government property that interferes with the Contractor's work. Such equipment, materials, or property shall be identified in the Contractor's construction plans, and approved by the Contracting Officer. At the completion of work, the Contractor shall replace the relocated items, reconnect any utilities or other interfaces, and demonstrate that the equipment is functional as it was in its original condition. The Contractor is responsible for repairing any damage incurred to the equipment during relocation at no charge to the Government.

3.8.2.5 Condition of Structures: The Government assumes no responsibility for the actual condition of structures prior to the start of construction. Conditions existing at the time of inspection for proposal preparation purposes will be maintained by the Government insofar as practical. Prior to starting construction, the Contractor shall record, in the presence of the Contracting Officer, the actual condition of structures, equipment, and facilities adjacent to the areas of alteration or removal. This record of existing site conditions shall be submitted and approved prior to the start of construction work.

3.8.2.6 Building Modifications: The Contractor shall modify sections of Building 1247B and other buildings or structures as required to facilitate demolition of the existing equipment and installation of the new Power Supply equipment. Building modifications shall be identified in the Contractor's construction plans and supported with architectural and structural drawings.

The Contractor shall provide temporary shoring and bracing as required to support building structures and prevent settlement or other movement of foundations, building walls, and roofs.

Upon completion of the work, the Contractor shall restore modified buildings to their original functional condition.

3.8.2.7 Utility Services: Prior to the start of construction work, utilities serving each area of alteration or removal will be shut off by the Government and shall be disconnected and sealed by the Contractor.

All active utilities traversing the project site shall be preserved in operating condition, unless approved otherwise by the Contracting Officer. The Contractor shall repair damage to any such utilities caused by work under this contract, as approved and directed by the Contracting Officer.

3.8.2.8 Obstruction Lights: FAA approval to erect or operate all elevated structures, including cranes, exceeding 100 feet above ground level shall be obtained prior to all site activity that may exceed this height above grade. Obstruction markings and lighting, complying with the requirements of FAA AC70/7460-1, shall be continually maintained and operated for the duration that the elevated structures remain on site at or above the 100 feet elevation.

3.8.2.9 Burning: Burning of materials from demolished structures will not be permitted on Government property.

3.8.3 DEMOLITION OF EXISTING EQUIPMENT

3.8.3.1 General: The Contractor shall demolish the equipment as shown 'removed' on the Contract drawings, and as necessary for the new system design. All demolished equipment remains the property of the Government, except for the three outdoor transformers. The Contractor shall load onto his trailer all removed equipment from the work area. The Contractor shall deliver this equipment to, and offload at, an onsite salvage yard. The distance from the work area to the salvage yard is approximately 0.25 mile of paved roads.

The Contractor shall be responsible for offsite removal of all miscellaneous debris, construction rubble, and demolition waste. The Contractor shall maintain a dumpster at the work site and be responsible for prompt emptying or removal of the dumpster when full. The Contractor shall be responsible for clean up of any overflow, spillage, or dispersal of trash occurring prior to the dumpster removal.

The Contractor shall specifically be responsible for the removal of the three existing outdoor transformers from the site. The transformers shall be handled in an approved manner for the level of Polychlorinated Biphenyls (PCB) content in each transformer. The Government has previously measured the following levels in each transformer, however, the Contractor shall take an oil sample and have the levels of PCB confirmed. A certified copy of the sample data shall be submitted to the Government with the Demolition Plan.

Transformer TR-R: <5.0 PPM of PCB

Transformer TR-1: <1.5 PPM of PCB

Transformer TR-2: 12.1 PPM of PCB

The Contractor shall handle the transformer removal and disposal in accordance with the requirements in the Construction Specification, Section 01060, 1.6.2.5. Specific data for each transformer is shown on Contract Drawing 761539.

3.8.3.2 Demolition Plan: The Contractor shall submit a Demolition Plan, for Approval by the Contracting Officer, 30 calendar days prior to the start of demolition work. The Demolition Plan shall identify the Contractor's demolition scope and methods, and include the following details.

- a. A complete list of the equipment, materials, and structures to be demolished, modified, salvaged, or temporarily/permanently relocated.
- b. Drawings and/or descriptions of the cranes, cribbing assemblies, and rigging assemblies proposed for the demolition work.
- c. A demolition procedure describing the step-by-step approach for the demolition and removal.
- d. Drawings of proposed structural and architectural modifications to Building 1247B and structures.
- e. Proposed demolition crew trades mix.
- f. A demolition schedule identifying the planned demolition start date, duration, and interfaces.
- g. Method of removing from site and disposing of demolished equipment.
- h. Methods to protect existing equipment adjacent to or near the demolition area.
- i. A plan to handle the removal of the three transformers in accordance with the Construction Specification Section 01060, 1.6.2.5.

The Contractor shall not begin any demolition work until the Contracting Officer has approved the Demolition Plan.

3.8.3.3 Electrical Interfaces: Cables and wiring shall be pulled back to the first facility junction box that will not be removed as part of the demolition. Wiring shall be tagged with a label as to the junction box and terminal number from which it was removed. Wiring shall be wrapped and protected from damage during relocation.

3.8.3.4 Mechanical Interfaces: Mechanical hardware shall be disconnected at the nearest convenient connection to existing services that are to remain. Piping shall be disconnected at unions, flanges, valves, and fittings.

3.8.3.5 Concrete: Where required by the Contractor's design, existing concrete shall be demolished, removed, and disposed of. Square, straight edges shall be provided where existing concrete adjoins new work and other locations. Existing steel reinforcement shall be protected where indicated, otherwise, it shall be cut off flush with face of concrete.

3.8.4 MODIFICATIONS TO EXISTING COOLING WATER SYSTEM

3.8.4.1 General: The Contractor shall use the existing cooling water system to supply cooling water to the new Power Supply heat exchangers. The Contractor shall integrate the design of the Power Supply equipment with the existing cooling water properties, available flow rates, pressures, and temperatures.

The Contractor shall determine the quantities of cooling water required. Cooling water calculations shall be based on the data provided in Appendix B.

3.8.4.2 Cooling Water System Modifications: The Contractor is required to integrate the design of the Power Supply with the existing cooling water system. The Contractor shall provide the materials and labor to install all interconnecting piping and devices to connect the existing cooling water system to the new Power Supply equipment.

3.8.4.3 System Cleaning: The Contractor shall flush and clean all new cooling water piping after installation by a method approved by the Contracting Officer. System jumpers and strainer screens shall be used during the flushing process to catch foreign matter prior to entering new equipment. The screens shall be removed and inspected periodically during the flushing process until no foreign matter is detected on the screens.

3.8.5 INSTALLATION OF NEW POWER SUPPLY SYSTEM

3.8.5.1 General: The Contractor shall provide all engineering, labor, materials, and equipment to assemble, install, set-up, and activate the new Power Supply system.

3.8.5.2 Site Installation Plan: The Contractor shall submit a Site Installation Plan, for Approval by the Contracting Officer, 30 calendar days prior to the start of installation work. The Site Installation Plan shall identify the Contractor's installation scope and methods, and include the following details.

- a. Drawings and descriptions of the cranes, cribbing assemblies, and rigging assemblies proposed for the installation work.
- b. An installation procedure describing the step-by-step approach for the installation of each major component and sub-system.
- c. Drawings of proposed structural and architectural modifications to Building 1247B and structures.
- d. Proposed installation crew trades mix.
- e. An installation schedule identifying the planned installation start date, duration, and interfaces of each major component or sub-system to be installed.
- f. Methods proposed to protect existing equipment adjacent to or near the installation area.

The Contractor shall not begin any installation work until the Contracting Officer has approved the Site Installation Plan.

3.8.5.3 Input/Isolation Transformer: The transformer shall be provided assembled and factory tested. Components and accessories shall be completely installed, wired, and interconnected. Only a minimal amount of field connections shall be required.

The Contractor shall provide all materials and labor required to install the Input/Isolation Transformer at the field site. The installation work shall include:

- a. Civil work necessary for soil grading, foundation pads, curbs, gravel yard, steel support structures, demolition of existing equipment and construction of new equipment.
- b. Rigging to set and secure the transformer.
- c. Interconnecting piping and accessories for the cooling system and other auxiliaries.
- d. Connection of the new air switch and breaker(s)
- e. Interconnecting wiring between the transformer secondary and the Power Supply.

The methods used for installing the transformer shall be detailed in the Contractor's Site Installation Plan.

3.8.5.4 Filter Network: The Contractor shall provide all labor and materials required to install and connect the Filter Network at the site. The installation work shall include:

- a. Civil work, if necessary, for soil grading, foundation pads, gravel yard, and steel support structures.
- b. Installation of filter components.
- c. Suitable fence or enclosure around filter components.
- d. Connection to power bus as required by the Contractor's design.

The methods used for installing the filter network shall be detailed in the Contractor's Site Installation Plan.

3.8.5.5 Switchgear: The Contractor shall provide all labor and materials required to install and connect the switchgear at the site. The installation work shall include:

- a. Civil work, if necessary, for soil grading, foundation pads, gravel yard, and steel support structures.
- b. Installation of switchgear components.
- c. Suitable fence or enclosure around switchgear components.
- d. Connection to primary cables and to transformers as required by the Contractor's design.

The methods used for installing the switchgear shall be detailed in the Contractor's Site Installation Plan.

3.8.5.6 Power Supply: The Power Supply shall be provided with all integral components and accessories completely installed, wired, and interconnected. A minimum amount of field connections shall be required for site installation of the Power Supply.

The Contractor shall provide all materials and labor necessary to completely install the Power Supply at the field site. The installation work shall include:

- a. Preparation and re-surfacing as required of the floor in Bldg. 1247B prior to the Power Supply installation.
- b. Rigging as required to move and set the Power Supply into position.
- c. Assembly of the Power Supply sub-systems and components into a fully integrated and functional unit.

- d. Connection of input cabling from the input isolation transformer and output cabling and bus work to the existing arc-heater isolation switch.
- e. Interconnecting piping between the Power Supply cooling system and the existing cooling water piping.
- f. Tunnel controls interface.
- g. Interconnecting wiring between Power Supply control centers and existing protective relay panel.

The methods used for installing the Power Supply shall be detailed in the Contractor's Site Installation Plan.

3.8.6 DAMAGED SURFACES

Any portion of existing finished surfaces, of either the new Power Supply system equipment, or the existing facility equipment, which is found to be damaged as a result of the site construction work shall be patched with matching material.

3.9 POWER SUPPLY COMMISSIONING

3.9.1 SCOPE

The Contractor shall supply all travel, labor, materials, test equipment, and personnel to demonstrate that the integrated Power Supply meets the performance requirements of Section 3.1. The Power Supply commissioning shall include the following:

- a. Commissioning Plan.
- b. Sub-system inspections and tests.
- c. Integrated systems tests, at various power levels, for specified, pre-determined periods of time.
- d. Demonstration to the Government of fault tolerance and failure modes.
- e. Commissioning test reports and final documentation.
- f. Technical support and training.

3.9.2 COMMISSIONING PLAN

The Contractor shall submit a Commissioning Plan, for approval by the Contracting Officer, no later than 30 calendar days prior to the start of commissioning. The Commissioning Plan shall outline the testing procedure to bring the Power Supply on line in a safe and orderly sequence. The plan shall be written to progressively

and conservatively increase the level of system complexity, power consumed, and integration with the existing tunnel systems. It shall also be devised to progressively reduce risk and eliminate areas of uncertainty. The Commissioning Plan shall include testing and results that demonstrate compliance with all performance specifications in Section 3.1.2

The Commissioning Plan shall include the following testing phases and details.

- a. Personnel, equipment, and facilities required by the Contractor to perform commissioning.
- b. Subsystem verification tests.
- c. Integrated systems tests including no-load, partial load, and full load tests.
- d. Pre-operational checklists.
- e. Test procedures and instructions.
- f. Test acceptance and sign-off.

3.9.3 GENERAL COMMISSIONING REQUIREMENTS

3.9.3.1 Commissioning Personnel: The Contractor shall provide full time engineers employed specifically for commissioning of this Power Supply. These engineers shall be employed by the Contractor and shall not be subcontract personnel.

Site commissioning personnel shall have requisite experience in electrical equipment checkout and startup. All personnel shall be trained on the specific type of equipment used on this project, and shall be educated by the Contractor as to this specific project requirements and performance criteria.

A commissioning engineer shall be provided as a single point of contact on site to oversee and coordinate the Contractor's commissioning activities. This engineer shall be on-site whenever commissioning tests are performed and shall be responsible for the safety and success of each test.

3.9.3.2 Test Equipment: The Contractor shall provide all test and recording equipment. The equipment shall be calibrated and maintained in accordance with the Contractor's quality assurance program. Any data recorded on untraceable or expired calibration certified equipment will not be accepted by the Government.

3.9.3.3 Commissioning Parts: The Contractor shall replace or repair all damaged parts, consumables, defects, and warranty work

associated with the Power Supply during commissioning. Components shall not be taken from the spare parts to be provided under Section 3.9.7.

3.9.3.4 System Measurements: The Contractor shall perform and document system measurements on the completely installed Power Supply to verify that the required system performance parameters have been met.

3.9.4 SUBSYSTEM VERIFICATION INSPECTIONS AND TESTS

3.9.4.1 General: Prior to commissioning the fully integrated Power Supply, the Contractor shall perform factory or on-site subsystem tests of the individual Power Supply components and subsystems. Subsystem tests shall include all de-energized tests and verifications of all equipment after system site installation.

All initial tests shall be conducted at the lowest energy level required to perform the test. The Government and the Contractor shall both agree when each phase has been completed, and the Power Supply is ready for the next level of testing.

The Contractor shall perform subsystem inspections and tests in accordance with the applicable industrial standards and codes, the Contractor's or manufacturer's standard practices, and the Contractor's Quality Assurance Plan.

The Contractor shall submit Certified Inspection Reports and Certified Test Reports no later than 21 calendar days after completion of the inspections or tests.

The Contractor shall perform, as a minimum, the following commissioning items.

- a. Perform site delivery inspections
- b. Confirm site location, bolts, conduits, and sub-element interfaces
- c. Provide equipment engineers required at installation leveling, bolting down, and connection
- d. Flush and check for contamination of fluid systems
- e. Pressure test fluid systems
- f. Perform continuity checks of electrical circuits
- g. Perform voltage test circuits
- h. Confirm control and monitoring power supply polarities

- i. Check all fan and pump rotations
- j. Check permissive sequences
- k. Certify safety procedures
- l. Certify grounding and shielding circuits
- m. Certify hardwired fail-safe circuits
- n. Certify protective device coordination
- o. Certify analog inputs and outputs
- p. Install Power Supply controller software and verify parameters
- q. Certify diagnostics are operational
- r. Operate all disconnecting and devices, both manually and automatically.

3.9.4.2 Input/Isolation Transformer: Subsystem inspections and tests of the Input/Isolation Transformer shall include the following:

- a. Windings of the transformer shall be given an insulation resistance test insulation resistance test set. The test shall be applied for not less than five minutes and repeated until three equal, consecutive readings, one minute apart, are obtained. Readings shall be recorded every thirty seconds during the first two minutes and every minute thereafter. The minimum acceptable resistance shall be 100 megohms.
- b. Upon satisfactory completion of the insulation resistance test, each transformer winding shall be subjected to a high voltage DC withstand test. The test voltages shall be equal to at least 75 percent of the DC high potential test of the factory test values, and shall be applied for one minute.
- c. Upon satisfactory completion of the high voltage withstand test, each transformer winding shall be given a second insulation resistance test. The results of the second insulation resistance test shall approximate the first test and shall indicate no evidence of permanent injury by the high-potential test.
- d. Turns Ratio Test.
- e. DC dielectric test.
- f. Insulation power factor test (Doble Test)

The primary windings of the transformer shall be disconnected from the power source, and the secondary windings of the transformer shall be grounded, before conducting insulation and high voltage tests on primary windings. Secondary windings of the transformer shall be disconnected from the secondary feeder system, and the primary winding of the transformer shall be disconnected from the power supply and grounded, before conducting insulation and high voltage tests on secondary windings.

3.9.4.3 Filter Network: Subsystem inspections and tests of the Filter Network shall include the following:

- a. Verify control and power interfaces.
- b. Insulation resistance test on installed filter network including each capacitor and inductor.
- c. Measure capacitor and inductor values.
- d. Verify control, interlock, protective device, and grounding operation on installed system.
- e. Verify operation and perform tuning optimization of harmonic filters.

3.9.4.4 Switchgear: Subsystem inspections and tests of the switchgear shall include the following:

- a. Verify control and power interfaces between all subsystem component interconnections.
- b. Resistance measurement of each installed air switch power contacts and breaker power contacts with a digital low resistance ohmmeter.
- c. Insulation resistance test on installed air switch and breaker.
- d. Initial setting and calibration of protective relaying components in accordance with the protective coordination study requirements.
- e. Verify control, interlock, protective relaying, and grounding operation on installed system.

3.9.4.5 Power Supply: Subsystem inspections and tests of the Power Supply shall include the following:

- a. Verify function of remote control and monitoring devices.
- b. Verify function of local control and monitoring devices.

- c. Verify function and calibration of all field sensors.
- d. Verify operating sequence of startup, loading, unloading, and shutdown.
- e. Verify unloaded and loaded harmonic distortion output of the Power Supply at PCC is within recommended limits of IEEE 519 and requirements of this Specification.
- f. Verify function and redundant operation of the cooling system.
- g. All low voltage Power Supply bridge and control system tests.
- h. Test mechanical operation and electrical settings of all breakers, protective devices, and disconnecting devices.

3.9.5 INTEGRATED SYSTEM TESTS

3.9.5.1 General: This phase starts the actual site commissioning of the integrated Power Supply. Contractor shall allow the Government time to present the results of the subsystem verification inspection and tests to facility personnel to obtain authorization to proceed with integrated system tests. The Contractor shall allow a minimum of one week for this activity after successful completion of required subsystem tests.

All initial tests shall be conducted at the lowest energy level required. The Government and the Contractor shall both agree as to when each phase has been completed, and the Power Supply is ready for the next level of testing.

3.9.5.2 No-load System Tests: This phase shall begin with the energization of the medium voltage electrical system and activation of all equipment to energize the Power Supply automatically. The Power Supply shall then be operated locally, and at the Remote control panel. All sequencing and subsystem operations shall be deemed satisfactory by the Government prior to load testing.

3.9.5.3 Full Load System Tests: The Power Supply shall be sequenced up to full power, based upon a test matrix provided by the facility operators. The Power Supply shall be exercised sufficiently to demonstrate that the Power Supply and all auxiliaries are operating satisfactorily.

3.9.5.4 Acceptance: The Contractor shall provide a written test sequence and all test equipment to fully and unconditionally load the Power Supply to capacity and record system variables that prove the performance criteria of Section 3.1.2 has been met. The

test program shall be for sustained periods until all system parameters have stabilized at each load condition prior to taking acceptance measurements.

3.9.6 SPECIAL TOOLS

All special tools and special test equipment (one each) not otherwise commercially available required for the maintenance, troubleshooting, testing, and repair of the Power Supply shall be furnished as part of this contract.

The requirements of this section do not include activation and checkout parts as defined in other sections of this Specification.

The special tools shall be turned over to the Government at the completion of the commissioning phase.

3.9.7 SPARE PARTS

The Contractor shall provide the following Power Supply spare parts as part of this contract.

Input/Isolation Transformer:

- a. One set of spare gaskets for bushings manhole covers, relief covers, and flanges shall be provided with oil filled transformers. All gaskets shall be reusable rubber with means provided for controlled compression. This set shall be in addition to any gaskets used prior to contract acceptance. The gaskets shall be hermetically sealed in a packaged to prevent deterioration prior to use.
- b. One surge arrestor.
- c. One primary bushing/termination.
- d. One secondary bushing/termination.
- e. One spare fan (if fans are required).
- f. One spare oil pump (if oil pumps are required).

Harmonic Filter Network:

- a. One of each value capacitor.
- b. One of each value reactor.
- c. Three of each type fuse.
- d. Ten of each indicator light.
- e. One of each type control relay.

Switchgear:

- a. Three of each type fuse, including power and control.
- b. Ten of each type indicator light.

Power Supply:

- a. One set of thyristors to complete one bridge leg.
- b. Two firing module subassemblies.
- c. Two snubber circuits.
- d. One of each type of replaceable printed circuit boards.
- e. One each of all replaceable air and water cooling system filters and cartridge elements.
- f. One of each type potential transformer (PT) and current transformer (CT).
- g. One control power supply of each type used.
- h. One each surge arrestor.
- i. One each reactor.
- j. One each sensor used on cooling water system.
- k. One each type cubicle cooling fan.
- l. Three each type fuse.
- m. Spare indicator light bulbs, one for each indicator.
- n. One printer ribbon or toner cartridge for each type of hardcopy device supplied.

The Contractor shall configure and install all spare circuit boards and demonstrate operation of the Power Supply to be identical to the baseline circuit board arrangement.

3.9.8 PERSONNEL TRAINING

The Contractor shall be responsible for providing training of Government employees. The Contractor shall submit a complete set of Training material for Approval by the Contracting Officer, two weeks prior to beginning the training session. The Contractor shall conduct the training program at the NASA Langley Research Center and provide all experienced and qualified personnel and relevant materials required to implement the training program. Approximately 5 Government representatives consisting of engineers, operators, and technicians will attend the training. The training will be held at a time mutually agreeable to the Government and the Contractor.

3.9.8.1 Content: The program shall be designed to train personnel in the operation, troubleshooting, and servicing of the complete Power Supply system; including all auxiliary equipment required for complete system operation.

3.9.8.2 Facilities: The Contractor shall conduct the training in the conference room at a location specified by the Government. Two overhead projectors will be provided for the Contractor's use. A minimum of 32 hours of training shall be provided. Hours for the training class shall be 8:00 AM to 4:30 PM, Monday through Friday, excluding holidays.

3.9.8.3 Materials: The training materials shall consist of lectures, videos, slides, and handouts that give an overview of the system operation. Detailed coverage of the power electronics

and components, cooling system, thyristor firing circuits, controllers, and software functions of the Power Supply shall be included. Handout materials shall become the property of the Government, and the Contractor shall supply a minimum of 2 additional copies of the handouts as part of the training material package.

3.9.8.4 Software Training: The Contractor shall also provide in-depth training on the Power Supply controller software programming. This shall consist of the Contractor's commercially available training program tailored to this specific element of the Power Supply. This training shall be provided at the Contractor's facility, conducted in the English language, and be completed prior to site delivery of the Power Supply. The training program will be attended by a maximum of three Government authorized engineers and experienced technicians to familiarize the Government with the software control aspects of the Power Supply prior to commissioning.

3.9.9 FOLLOW-ON SUPPORT

3.9.9.1 Warranty Work: The Contractor shall provide trained and skilled personnel to repair the Power Supply equipment for the duration of the system's warranty period. The Contractor shall provide all manuals, spare parts, and test equipment required for warranty repairs.

3.9.9.2 Reconfiguration and Other Support: As part of the follow-on support, the Contractor shall provide up to 40 hours of technical support at the NASA Langley Research Center for reconfiguration and other special maintenance needs of the Power Supply. This support shall be provided for up to twelve months from the date of final acceptance.

PART 4 PERFORMANCE ASSURANCE

4.1 SCOPE

The Contractor shall be responsible for developing, submitting, and implementing an approved Quality Assurance (QA) Program. The Contractor shall be responsible for implementing all facets of the program, and maintaining the QA documentation.

The Contractor's QA Program documentation shall be submitted at the Project Kickoff Meeting. The Contractor's QA Program will be reviewed and approved based on the guidelines and criteria established in this section. The QA program shall meet the requirements of ISO 9001.

The Quality Assurance Program criteria and provisions identified herein shall be satisfied in addition to all detailed technical and performance requirements contained in the contract documents. Overlapping and interfacing requirements shall not result in duplication of the Contractor efforts.

The Government will audit the Contractor's QA Program on a continuous basis. Qualified personnel, in a manner that will not interfere with the Contractor's operations, will perform these audits.

The activities, materials, and execution of the contract specifications by the Contractor and/or subcontractors are subject to audit through review, witness, surveillance, monitoring, examination, testing and other means by the Contracting Officer and/or his technical representative. These audits will be conducted to determine the following.

- a. Functional activities, which control the quality, are performed in accordance with established requirements.
- b. The work complies with technical, functional, performance, and quality requirements as stated in the Specifications.
- c. Quality assurance documentation is complete and adequate.

4.2 CONTRACT QUALITY ASSURANCE PROGRAM

The contractor shall develop a Quality Assurance Program that describes in detail how the Contractor intends to implement his internal quality assurance activities and those of his subcontractors into an integrated overall approach to perform the requirements of this Specification.

The Contractor shall submit the documents and procedures referenced in his internal quality assurance plan for review. This submittal shall include any subcontractor or supplier QA

documentation as well. The interface points and controls shall be pointed out between the two sets of documents to indicate the integration of the overall Quality Assurance Program.

The Contractor shall report monthly on the status of the Quality Assurance Program. This report shall be included with other project monthly reporting requirements, and should include the following.

- a. Assigned quality control personnel.
- b. Descriptions on specific quality control, inspection, and verification tasks.
- c. Procurement and contract quality milestones and activities.
- d. Shop fabrication and manufacturing activities.
- e. Quality assurance management activities.
- f. Summary of nonconformance occurrences and corrective actions.

The Contractor's Quality Assurance Program shall address QA management, planning, and implementation; including organizational responsibilities and interfaces with engineering, purchasing, and manufacturing.

The Contractor shall identify the individual responsible for directing and managing the Contractor's Quality Assurance Program for this work, and his/her reporting relationship to the Contractor's Project Manager.

The Contractor shall establish, document, and implement design management and control measures on design related documents and deliverables as part of his QA Program.

The Contractor's procurement and subcontract documents shall identify and pass through to subcontractors, contractors, and suppliers all related quality control system and product quality criteria, and requirements, including Contractor required witness points and all other inspection requirements.

The Contractor shall establish and use a documented metrology system to control and calibrate measurement processes in order to provide objective evidence of quality conformance. Measures shall include the following.

- a. Identification and calibration status of equipment.
- b. Measurement standards traceable to the National Institute of Standards and Technology.

- c. Procedures for the calibration and use of measures and test equipment including prerequisites required for proper use.
- d. Identification and maintenance of calibration and metrology records.
- e. Remedial and preventive actions taken relative to non-conforming measurement standards or equipment used on contract deliverables.

The Contractor's QA Program shall address appropriate handling, packaging, and shipping requirements, and assure that components meet these requirements prior to leaving the point of manufacture. In addition, these requirements shall be maintained throughout all subsequent shipping, storage, installation, and set up.

The Contractor's QA Program shall include a component release system that culminates all QA activities on the component, and verifies its readiness to be shipped.

The following factory inspections shall be performed by the Contractor for each Power Supply component, sub-system, and assembly.

- a. Dimensions.
- b. Alignment and Fit.
- c. Device Functionality.
- d. Sub system components.
- e. Marking and Identification.
- f. Wiring.
- g. Workmanship.

The Contractor shall perform component interface verification. This effort shall require each major element's responsible project engineer to visit other manufacturer's site to physically verify that all major elements will mate with its counterparts electrically, physically, mechanically, structurally and functionally. This metric shall be written into the Quality Assurance plan for each component.

4.3 GOVERNMENT INSPECTIONS

The Contracting Officer or his technical representative at the point of equipment manufacture will perform the following inspections at no additional cost to the Government:

- a. Dimensions
- b. Marking and Identification
- c. Workmanship
- c. Performance testing
- e. Preparation for Shipping

The Contractor shall notify the Government in writing, 21 calendar days prior to the desired date of Government inspection, so that a mutually agreeable time can be arranged.

The Contractor shall address in his QA Program the application of inspection and examination to the fabrication, assembly, and testing for this contract. Examples of functional activities of fabrication and construction control include:

- a. Operations controls, including receiving, production, scheduling, assembly, shipping, and installation.
- b. Material controls, including identification, receiving, storage, handling, and issuance.
- c. Cleanliness controls, including work areas, equipment, shipment, and storage.
- d. Controls for special processes where uniformity and high quality cannot be assured by inspection of articles alone. Examples of these processes are:
 - 1. Metallurgical and chemical processes.
 - 2. Metal joining and welding processes.
 - 3. Handling processes.
 - 4. Heat treatment processes.
 - 5. Forming processes.
 - 6. Surface treatment processes.
 - 7. Environmental stress screening.
- e. Documentation Control

4.4 FASTENERS

The Contractor shall address in his QA Program procedures governing procurement and control of high strength fasteners with a minimum tensile strength exceeding 120,000 psi intended for use on this contract. These procedures must include positive lot traceability to certified tests and/or inspections. A torque traceability log including unique bolt identification methods shall be maintained by the Contractor to record and certify high

strength fastener torques. Torque wrenches and tensioning devices shall have up-to-date certifications and calibrations.

General purpose fasteners length and quantities shall be the Contractor's responsibility. Installed fasteners shall have a minimum 1-1/2 diameter engagement in tapped holes, and a minimum of two threads exposed when used with nuts and washers. Threaded inserts shall be required for all threaded applications into aluminum.

4.5 RELIABILITY ASSURANCE

Reliability assurance shall be a significant factor in the Government's input to the review process of the design, manufacture, and operational characteristics of the Power Supply.

To assure the Government that reliability is a characteristic of the Power Supply, the Contractor and subcontractors shall have demonstrated experience in the manufacture and construction of large Power Supplies as specified below.

- a. Engineering and design firms which design the Power Supply shall be experienced in the design of large, similar type Power Supplies.
- b. Firms responsible for the design of the input isolation transformer interface, Filter Network, and heater connections shall be experienced in designing similar medium voltage power distribution systems.
- c. Firms responsible for the Power Supply design shall be experienced in similar thyristor power conversion technology.
- d. Firms responsible for the design of the controls shall be experienced in solid-state processor technology, discrete controls and automation applications.

The Contractor shall be required to demonstrate throughout the duration of the contract that the Power Supply meets the following criteria for a reliable design.

- a. Components have been selected with ample design margins (no more than 80 percent of maximum values).
- b. Conservative duty cycles, compared with similar critical industrial processes, have been used.
- c. High quality manufactured goods and subsystem components have been selected.

- d. Redundancy has been implemented for all possible fault conditions that cannot be otherwise enhanced by improved methods of design or manufacture.
- e. Hardware has been specifically designed and checked for adequacy in this specific application.
- f. The integration of the components into a Power Supply strengthens the overall reliability and increases the MTBF, as opposed to stressing or overloading any one component of the system.

The Government reserves the right to examine all aspects of the Power Supply design, manufacture, and implementation to quantify and clarify any reliability concerns that are relevant to the performance criteria outlined above. The Contractor shall be responsible for satisfying and altering, if required, any aspect of the Power Supply that does not meet the above Specification criteria.

4.6 PERFORMANCE MONITORING

The Government will monitor the Contractor's performance throughout the life of the contract at no additional cost to the Government. Work performed directly or by subcontract shall be subject to Government review and inspection at any time and place. None of the Government's review, approval, and inspection activities shall be considered as part of, replacing, or enhancing the Contractor's Quality Assurance plans or implementation.

4.7 DOCUMENTATION

The Contractor shall establish, maintain, and implement procedures and policies for the identification, collection, indexing, storage, maintenance, distribution, and disposition of contract documentation, forms, and QA records. This shall include all inspection records, test reports, and field documentation, both Contractor, and subcontractor generated.

APPENDIX A

- Figure 1: 20 Megawatt Curve
- Figure 2: Operating Envelope
- Figure 3: DC Filter Inductance

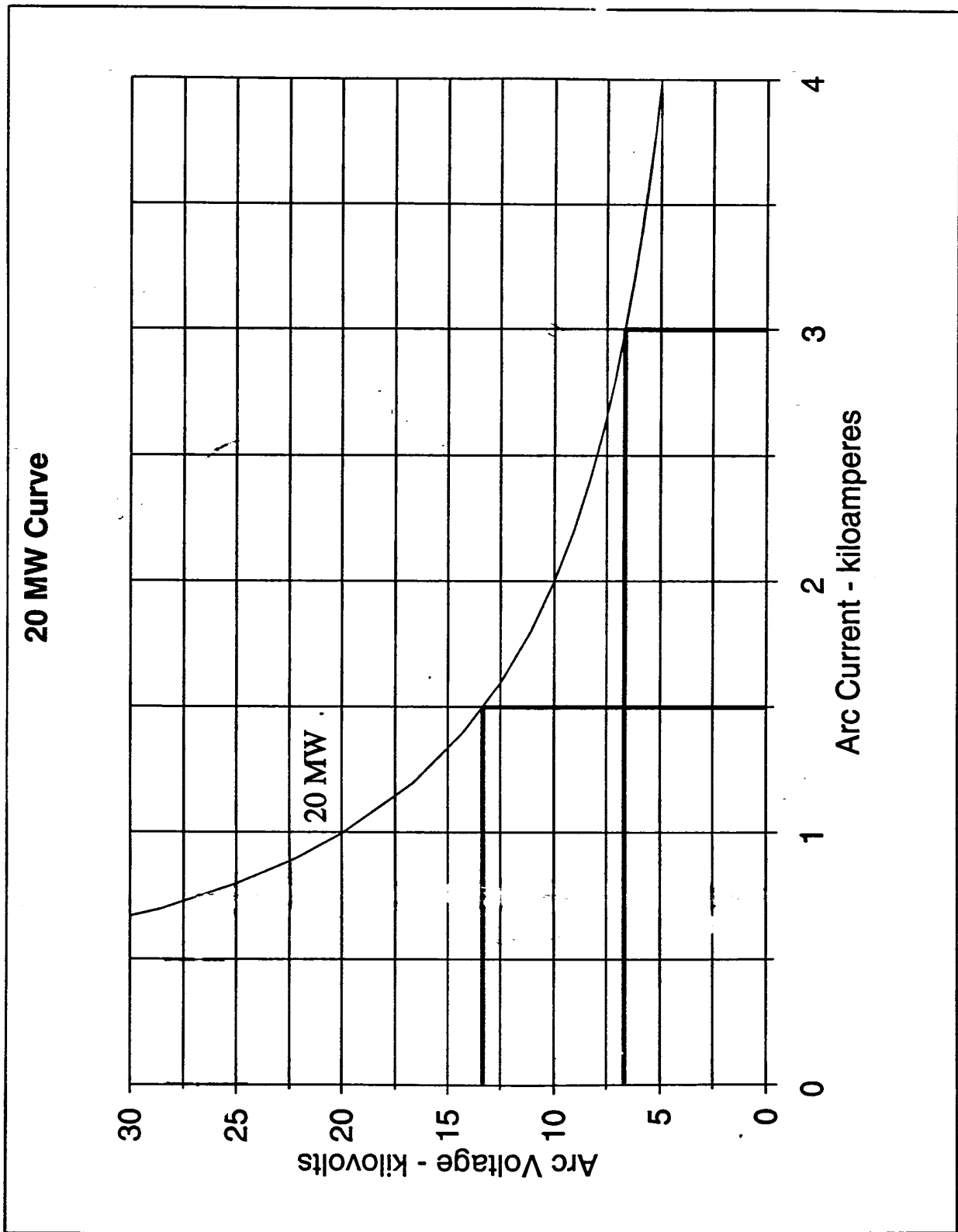


Figure 1
20 Megawatt Curve

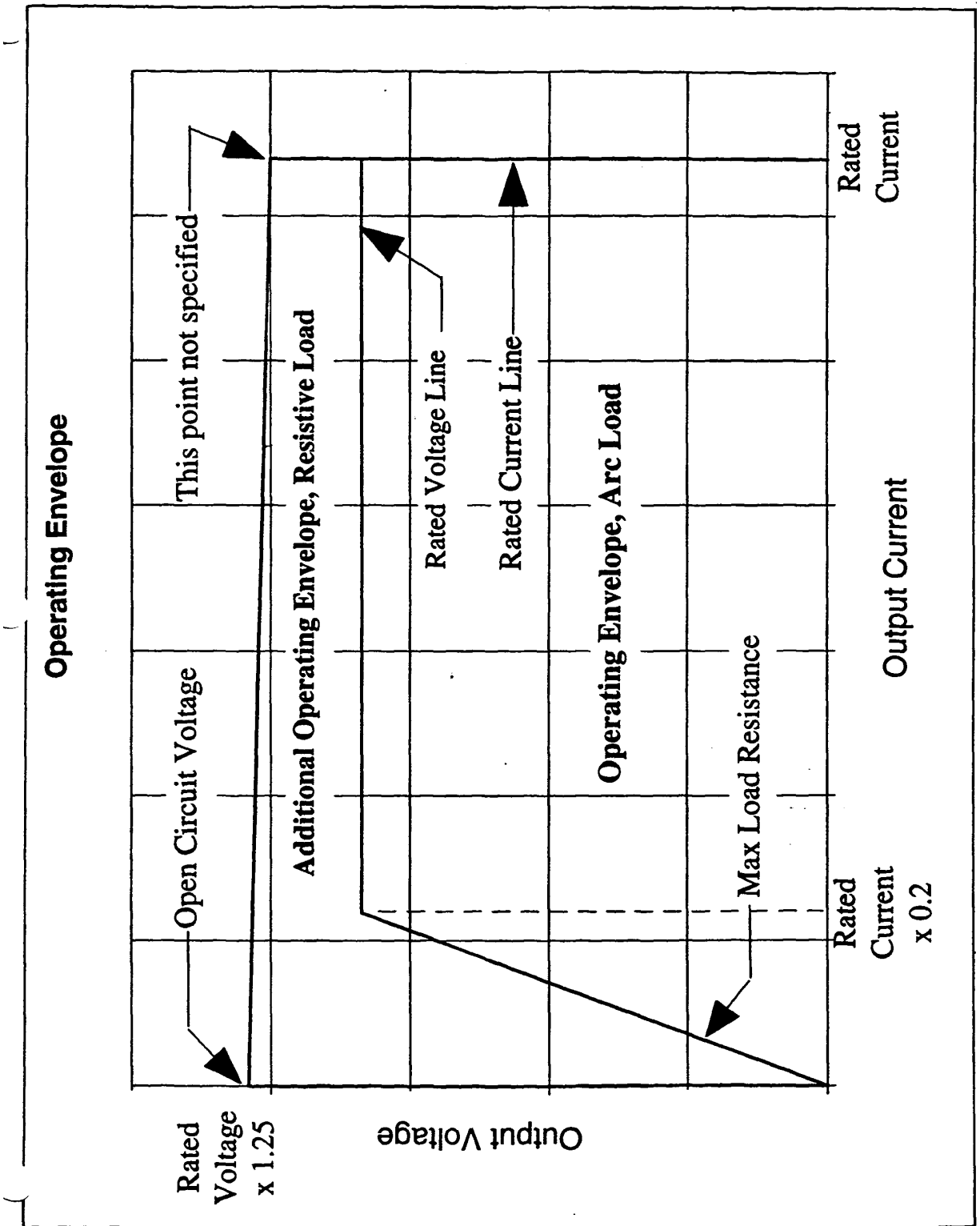


Figure 2
Operating Envelope

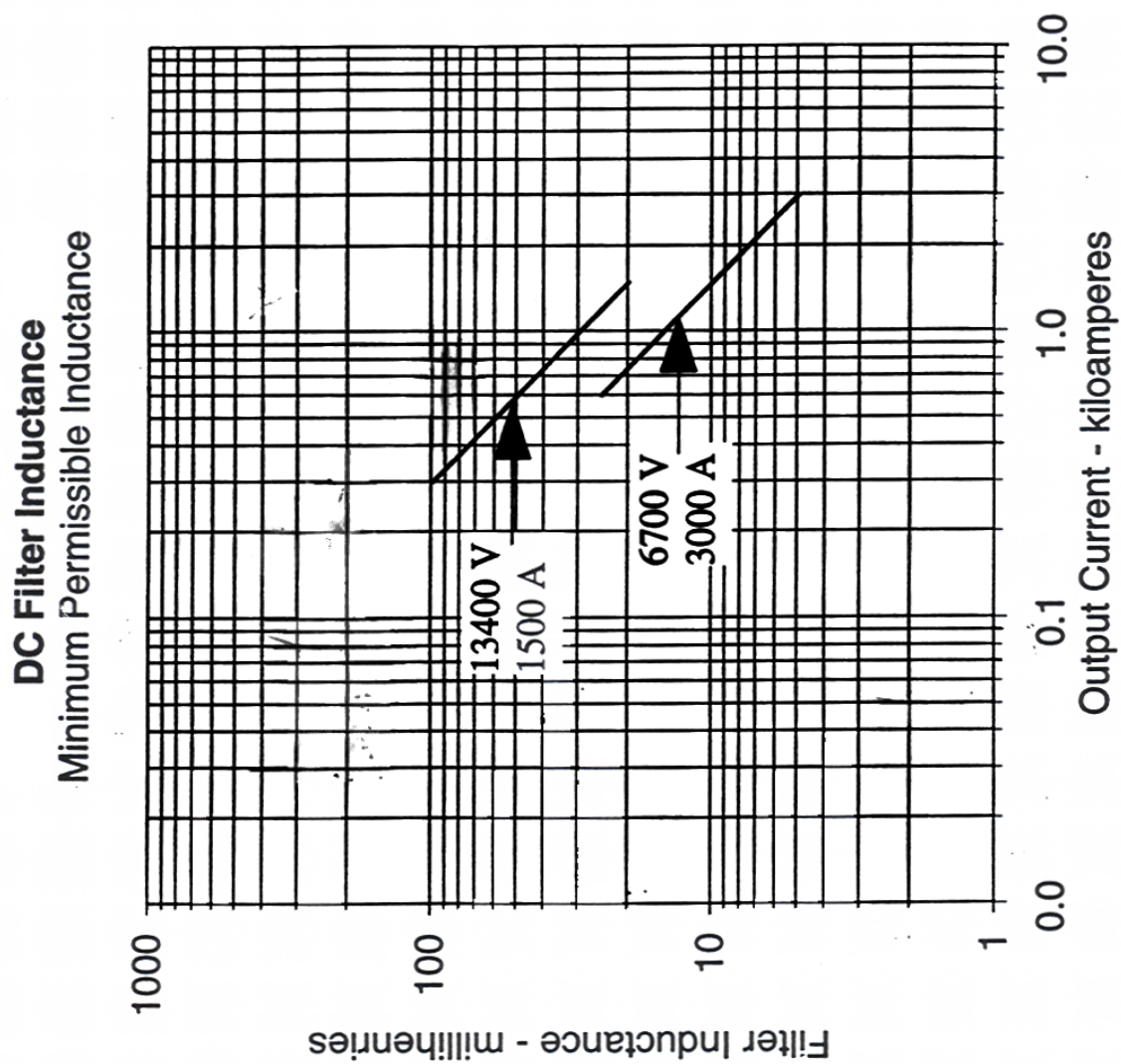


Figure 3
DC Filter Inductance

APPENDIX B

Building 1247B Cooling Water System Data

Cooling Water Design Data:

Maximum supply temperature:	85 Degrees F
Minimum supply temperature:	40 Degrees F
Nominal supply pressure:	70 psi

Maximum return water temperature:	95 Degrees F
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PH:	8.2
OPO4 (ppm) :	8.0
Conductivity (micro-ohms) :	800 - 500

APPENDIX C

FAULT PROTECTION DATA

Short Circuit Ampacity at Air Switch 3084:

<u>Inst. Asym.</u>	<u>AC Comp.</u>	<u>Half Cycle</u>	<u>Steady State</u>
49,570	28,619	40,333	16,107

X/R Ratio: 8.89

6600 volt wye system grounded through 2.11 Ω resistor